AD-753 449

TRAJECTORIES OF THE FUTURE

D. Gvishiani, et al

Foreign Technology Division
Wright-Patterson Air Force Base, Ohio

29 September 1972

FTD-HT-23-2128-71

FOREIGN TECHNOLOGY DIVISION

AIR FORCE SYSTEMS COMMAND

TRAJECTORIES OF THE FUTURE

by

D. Gvishiani and V. Lisichkin

FOREIGN TECHNOLOGY DIVISION

Approved for public release;
distribution unlimited.

UNCLASSIFIED
Security Classification

DOCUMENT CONTROL DATA - R & D	
(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)	
1. ORIGINATING ACTIVITY (Corporate author) Foreign Technology Division, Air Force Systems Command, U. S. Air Force	2a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED
	2b. GROUP
3. REPORT TITLE TRAJECTORIES OF THE FUTURE	
4. DESCRIPTIVE NOTES (Type of report and inclusive dates) Translation	
5. AUTHOR(S) (First name, middle initial, last name) D. Gvishiani and V. Lisichkin	

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
1968	90	

8a. CONTRACT OR GRANT NO.	9a. ORIGINATOR'S REPORT NUMBER(S) FTD-HT-23-2128-71
b. PROJECT NO.	
c.	9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)
d.	
10. DISTRIBUTION STATEMENT Approved for public release; distribution unlimited.	
11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY Foreign Technology Division, Wright-Patterson AFB, Ohio

13. ABSTRACT

Prognostics is a young science, not formed as yet. Its subject is methods of making forecasts, and its objects of application are social phenomena, economics, science, technology, etc. The authors, D. Gvishiani and V. Lisichkin, showed that the Marxist-Leninist philosophy in particular is the genuine basis of scientific predictions and the cornerstone of macro- and microprognoses. The authors have made an attempt to systematize prognosis methods. Of course we are concerned with all existing methods (such an operation is within the capabilities of only a collective of scientists not limited by the rigid frameworks of a popular brochure). But this was not the purpose of the authors. Their basic task is to attract the attention of the scientific community to prognostics and to show that there is already available an adequate number of prognosing methods which can successfully be applied in research and practical work. It seems to us that in this plan the authors have performed their task.

DD FORM 1 NOV 65 1473

UNCLASSIFIED
Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
R and D Forecasting Economic Forecasting						

EDITED TRANSLATION

FTD-HT-23-2128-71

TRAJECTORIES OF THE FUTURE

By: D. Gvishiani and V. Lisichkin

English pages: 90

Source: Prognostika, Izd-vo Znaniye, Moscow, 1968,
pp. 3-71.

Requester: FTD/PDBA

Translated by: Henry Peck

III A

TABLE OF CONTENTS

U. S. BOARD ON GEOGRAPHIC NAMES TRANSLITERATION SYSTEM

Block	Italic	Transliteration	Block	Italic	Transliteration
А а	*А а*	A, a	Р р	*Р р*	R, r
Б б	*Б б*	B, b	С с	*С с*	S, s
В в	*В в*	V, v	Т т	*Т т*	T, t
Г г	*Г г*	G, g	У у	*У у*	U, u
Д д	*Д д*	D, d	Ф ф	*Ф ф*	F, f
Е е	*Е е*	Ye, ye; E, e*	Х х	*Х х*	Kh, kh
Ж ж	*Ж ж*	Zh, zh	Ц ц	*Ц ц*	Ts, ts
З з	*З з*	Z, z	Ч ч	*Ч ч*	Ch, ch
И и	*И и*	I, i	Ш ш	*Ш ш*	Sh, sh
Й й	*Й й*	Y, y	Щ щ	*Щ щ*	Shch, shch
К к	*К к*	K, k	Ъ ъ	*Ъ ъ*	"
Л л	*Л л*	L, l	Ы ы	*Ы ы*	Y, y
М м	*М м*	M, m	Ь ь	*Ь ь*	'
Н н	*Н н*	N, n	Э э	*Э э*	E, e
О о	*О о*	O, o	Ю ю	*Ю ю*	Yu, yu
П п	*П п*	P, p	Я я	*Я я*	Ya, ya

* <u>ye</u> initially, after vowels, and after ъ, ь; <u>e</u> elsewhere. When written as ё in Russian, transliterate as yё or ё. The use of diacritical marks is preferred, but such marks may be omitted when expediency dictates.

Prognostics is a young science, not formed as yet. Its subject is methods of making forecasts, and its objects of application are social phenomena, economics, science, technology, etc. The authors, D. Gvishiani and V. Lisichkin, showed that the Marxist-Leninist philosophy in particular is the genuine basis of scientific predictions and the cornerstone of macro- and microprognoses. The authors have made an attempt to systematize prognosis methods. Of course we are concerned with all existing methods (such an operation is within the capabilities of only a collective of scientists not limited by the rigid frameworks of a popular brochure). But this was not the purpose of the authors. Their basic task is to attract the attention of the scientific community to prognostics and to show that there is already available an adequate number of prognosing methods which can successfully be applied in research and practical work. It seems to us that in this plan the authors have performed their task.

INTRODUCTION

However man is occupied with his everyday business, in his thoughts and dreams he always turns toward the future. It would not be an exaggeration to say that each day of mankind is lived for the sake of tomorrow's day. Naturally at all times the better minds attempted to predict the future and to foresee and prophetesies it. It was represented by the humanist scientists as some kind of rosy abstration, while at the beginning of the XIX century utopian socialism emerges with a censure of the capitalist system, opposing it with the socialist ideal of the public system.

Marxism first stated the problem of historical vision on a scientific basis. "Marx," wrote V. I. Lenin, "has not even a shadow of attempts to make a utopia, to conjecture emptily concerning that which cannot be known. Marx states the question of communism as a naturalist would pose the question of the development of a new, let us say, biological variety, once we know that it has somehow sprung up, and in some definite direction it is altered."

The strictly scientific investigation of the laws of the development of the capitalist method of production and the socio-economic formations which preceded capitalism permitted Marx and Engels to predict the inevitability of the revolutionary

transfer from capitalism to socialism, the dictatorship of the proletariat, and the construction of a classless society. The continuous accumulation of capital, its concentration and centralization are, as Marx proved, a collectivization of the means of production within the frameworks of bourgeois society and in a specifically capitalist form. The objective tendency of this historical process is as follows: the capitalist class turns into a comparatively small social group, redundant for the further development of production, retarding its progress. Thus, there appears the economic necessity of the socialist collectivization of the means of production. This is the interest of the working class - the basic productive force of bourgeois society. And it is clear that the liberating struggle of the proletariat and a socialist revolution is the logical expression of this objective historical necessity formed in the depths of the capitalist means of production itself.

The teaching of Marxism, its content, development and practical realization are historical proof of the possibility of the scientific prediction of not only the closest results of each stage of social development but also its more or less long-range results.

The materialistic investigation of the dialectic process in the development of society is the methodological basis of the scientific prediction. Marxism, noted V. I. Lenin, states questions of the "... historical soil not in the sense of only one explanation of the past, but also in the sense of the fearless prediction of the future and the brave practical activity, and the directions toward its realization ..."

Bourgeois critics of Marxism attempt to prove that any sociological prediction is a variety of social sorcery and should be strictly evaluated as an attempt to previously tie the hands of people with a perspective, as it were, illusive historic fate.

The absurdity of these accusations is clear to each person with the slightest knowledge of historical materialism.

It is also easy to understand that the negation of the scientific sociological prediction reflects the political interests of the reactionary bourgoisie, which fears the future and therefore does not wish to see the forthcoming on the present tendency. The bourgeoisie sees its past in the present the same time as Marxism examines history not only from the standpoint of the past, but also from the standpoint of the future.

In the theoretical relationship the denial of the sociological prediction is a denial of the law of social process, the connection of social phenomena, a definite direction of social development at each given step of the history of society. Sociological prediction is inseparable from the scientific theory of society. To deny this means rejecting the possibility of the theoretical investigation of socio-historical process.

It is known that the most serious prophets, or as they are sometimes called, futurologists, in capitalist countries are ever more clearly beginning to perceive that the predicting of scientific-technical progress can be substantiated only under the condition of a complex approach to solving this problem, which includes, together with the scientific-technical and economic analysis, the analysis of tendencies of social development. However, the absence of scientific methodology of recognizing social phenomena causes extreme difficulties, as a result of which social prognoses bear, as a rule, a positive, empirical nature.

In the countries of the socialist camp and within the frameworks of the CMEA work is definitely being done in this direction. There is every reason to assume that these investigations will henceforth develop intensely. A critical study of the experience and investigations in the region of the procedure of prediction

in the developed capitalist countries is of important significance. In connection with this it is advisable to more actively use the available possibilities of cooperation with various national and international organizations occupied with questions of prediction. At the same time caution should be observed concerning the known overestimation of the achievements in this field available in the West, in which individual authors make assumptions.

Developing the procedure of the scientific-economical, sociological predictions and critically using all this valuable material, which is available in this relationship in foreign investigations, we must not forget for one minute that the genuine scientific value of prognoses, regardless of whatever sphere of social life they relate to, can be assured only under the condition that the prognoses are based on the Marxist theory of the development of human society.

Marxism-Leninism is a theoretical basis of not only global, so to say, strategic scientific prediction of the development of society, but also the basis for operational, tactical, microscale predictions whose significance is especially great in controlling the current social processes, in the systematic development of economics and culture, in perspective planning. The experience of the socialist structure has proven without a doubt that the correct creative application of the Marxist-Leninist theory assures both long-term and short-term predictions of the process of social changes.

From the moment of its birth, the Soviet State has demonstrated the possibility and necessity or predicting the development of economics, science, and technology. The genial sample of prognosis is the Lenin "Sketch of the Plan of Scientific-Technical Operations." Without exaggeration it can be said that the history of the modern scientific-technical and economic predictions begins with this document. A huge role was also

played by the plan for electrifying Russia developed in 1920-1922 on Lenin's initiative (the GOELRO plan), the first standard plan-prognosis in history for several decades.

Planning is inherent to the socialist system of economy. Nationally discussed annual and perspective plans for developing the national economy and directives for developing perspective plans is the fixed basis of our socio-economic development. The general perspective of the socio-economic development of socialist society found its scientific basis in the Program of the CPSU.

The development of socialist economics is unthinkable without completing the forms and methods of control, planning, and predicting. Together with the ever deeper development of the socio-economic prediction, its various directions are differentiated, first on science and technology. The necessity in differentiating is dictated by the requirement of finding special ways and means of evaluating the perspectives of the development of a particularly given branch of science or technology and the huge mass of data which require the appropriate special processing. However, together with this a reverse tendency acts on it - the integration of all scientific, technical and economic progneses caused by the requirement of obtaining the overall socio-economic picture of the future. Moreover, even the deepest technological prognoses will suffer one-sidedness and lose their value without the organic connection with the problems of social development. Therefore, all plans of developing the national economy provide not only economic, but also socio-political development. In just this way the plans of individual enterprises to an ever greater extent become plans of not only economic and scientific-technical development but also the social development of each individual enterprise.

Scientific-technical measures do not exist independently of economic measures. Both these and others are connected and form the socio-political conditions of life and of the individual enterprise and of society as a whole.

The perspective planning of the development of the national economy requires a thorough analysis of the tendencies in the development of various branches of science and technology, and the development of prognoses by the individual, most important directions of scientific-technical progress. In the final analysis such types of prognoses are the basic elements of the complete prognoses of the entire national economy. Therefore it is absolutely right to consider scientific-technical prognoses as specific subsystems in a broader system of social and economic prediction.

The planning order accepted in our country assumes the development of the basic directions in the evolution of science and technology based on predicting the forthcoming development of the most important tendencies of scientific-technical progress which are established after their confirmation as the basis of perspective plans in the development of the national economy.

At present there are developed long-term prognoses on the most important branches of the national economy. These prognoses are constantly corrected with the consideration of new data and new factors advancing the current work on operational planning. In this work, organized by the State Committee of the Council of Ministers of the USSR on science and technology, the Academy of Sciences of the USSR and its corresponding industries the most important scientists and specialists of our country are taking part. Since the basis of the prognoses depends on how deeply the tendencies which determine the development of the object are explained, great significance is taken on by a thorough assemblage of the original materials, their systematization and analysis, and the consideration of a multitude of factors influencing the development of a given branch of science and technology, and economics. All of this makes the development of the scientifically based methodology of prediction necessary.

At present there exist numerous methods of predictions of which the overwhelming majority bear a purely empirical nature. However, the empirical approach to prediction is quite inadequate, since as a rule it is based only on past experience, which is by far not always used under conditions which have changed. The theoretical development of prediction problems, which permits basically approaching the selection of the methods of prediction, an evaluation of the accuracy of the prognoses to be obtained, a definition of the maximally possible and permissible periods of prediction, etc., is so necessary.

Stating and solving the theoretical problems involving prediction make up the new science formed in our time - prognostics.

CHAPTER I

PROBLEMS IN PREDICTING SCIENTIFIC TECHNICAL PROGRESS

Under the conitions of the modern scientific-technical revolution science is becoming a direct productive force of society. Its social role is increasing, and a qualitative shift is occurring - a more or less random and limited application of scientific approach to the structure, functioning, and development of material production. New discoveries in the field of basic sciences are ever more frequently generating new branches of production. Previously unknown possibilities of using scientific-technical achievements are discovered each year.

The scales and concentration of modern public production require the scientific control of all spheres of public life. Learning to control public production is the problem which Lenin persistently emphasized since the first days of the revolution as the most important problem of the working class, who took the government into their hands. The economic and technical potential of any country, its power and defense capabilities are now as never before closely tied in with the state and perspectives of the development of sciences and technology. Hence, a new but no less difficult and complex problem is learning to control the development of science and technology in the interests of social progress.

The most important component part of the control function is, as is known, the prediction and development of the perspective which consider the dynamics in developing the system to be controlled and the varying external conditions influencing it. The problem of controlling a scientific-technical process under the condition of an ever-accelerating scientific-technical revolution especially acutely advances the necessity of prediction, evaluating the perspectives, the social consequences, and the possibilities of developing science and technology at each individual step. The continuously growing necessity of prognoses involves the constant complication of all sides of the life of society, the tempos of the development of production forces, the interweaving of economics, science and technology, and the complex structure of the entire national economy. Therefore the growing interest in prognostic investigations is a regular consequence of the internal logic of developing human history.

The interconnection of many factors, the acute lack of time, and the innumerable multitude of possible solutions are the conditions in which we find it necessary to control the complex system of scientific-technical development. Hence there appears the necessity of introducing an additional link into the control chain for determining the results of this or that solution and the factors which can influence the object to be controlled. If we begin with data describing the system only at a given moment and do not consider the future conditions of its fluctuation, control will not be optimum. Moreover, the system could generally become uncontrollable.

The development of an effective technical and economic policy in unthinkable without prediction. The prognoses make it possible to plot the course of development to be oriented in the complex system of the interwoven branches of economics and technology, to substantially calculate the prediction requirements and to determine the place of investigating various problems in the broad

front of scientific-technical progress, and to develop perspective plans of capital investments, etc.

Technical progress is the basic moving force in the development of the national economy. However, a changeover in production during the mastery of a new technique often loses much time. In order for the introduction process not to interrupt the rhythm of production and not to stretch out in years it is first necessary to foresee the leading tendencies in the development of the technique and to determine the perspective devices and means for applying and mastering it. President of the Academy of Sciences of the USSR, Academician M. V. Keldysh, in his report at the General Assembly of the Academy of Sciences of the USSR in March of 1968 emphasized "... Great significance is taken on by the prognoses in the development of the most important branches into longer periods. The Five-Year Plans should not only solve the problems of a given five years but should also prepare future development."

The development of the national economy is predicted in several directions. The first direction involves investigating the relationship of the prognosis and the plan. Economic prognoses cannot exist independently of the plan. Based on the knowledge of the regularity of economics the prognosis in its function serves to determine the ways of developing the national economy. Therefore prognosis is a necessary stage in preplanning developments. At the same time the plan is limited by a certain time and by far does not include the consequences of the decisions taken in it. However, a consideration of these consequences is necessary for both the basis of the plan to be compiled and for considering the possibilities of the next plan. In this connection we should speak of predicting the consequences of the plan decisions for periods of time greater than the period planned for. And finally, the operational prognosis of the periods and conditions of solving the plan problems in the process of putting the plan into force.

The directions of economic prediction involve an analysis of the objects of the prediction.

Ordinarily four reinforced objects of economic predition are singled out:

scientific-technical progress (an analysis of the perspectives in the development of science and technology and their influence on the economy);

resources (labor and natural);

public requirements (production and nonproduction);

social conditions of reproduction (the consequences of scientific-technical progress, the growth of production forces, etc.).

These consolidated objectives of economic prediction are elements of a single system - the global prognosis of the country's national-economy development.

Prognoses of scientific-technical progress are the most important part of the economic prognoses, since the progress of science and technology to a great extent determine the tempos of the development of the entire national economy. Developing the prognoses of the scientific-technical progress is necessary in the main directions. they include: electrification, automation and cybernatization, automation and biologization. They involve progress in the appropriate branches of science and the application of the latest achievements in technology and industry. Mechanization, electrification, and automation were determined as basic directions in the technical rearmament of the national economy quite a while back, while cybernetics, automation and biologization are recently noticed tendencies in the technological application of basic sciences. Now we can show new tendencies of

scientific-technical progress connected with the conquest of space (the application of ground-based production to space), with the technological application of new physical effects (physics applications), etc.

Four types of prognoses of scientific-technical progress should be singled out:

prognoses of principally new (pioneer) inventions and discoveries;

Prognoses of the fields of applying new inventions and discoveries;

Prognoses of the appearance of new designs and machines;

prognoses of the wide application of discoveries, inventions, and designs already mastered in science and technology.

These four types of prognoses characterize the process of the materialization of scientific-technical creation, beginning with the appearance of the idea and ending with the industrial mastery and expansion of the invention. Each of them should be formulated inside the basic directions of scientific-technical progress.

Depending on the object scale of scientific-technical progress, 6 types of prognoses are ordinarily singled out;

worldwide scientific-technical progress;

the progress of science and technology within the boundaries of the individual country;

the development of complex technical problems (interbranch prognoses);

the development of individual branches of industry (branch prognoses;)

the development of individual types of production and technological processes (production-type prognoses);

the development of machine units and assemblies (part progneses).

The synthesis of all types and kinds of prognoses leads to the prognosis of scientific-technical progress as a whole. As a result it becomes possible to determine the worldwide and national level of scientific-technical development, to select the most promising technico-economical directions in solving actual problems of the economy, to reveal new fields in applying the scientific-technical achievements, and to evaluate the conditions for solving the most important scientific problems and the economic effectiveness of their practical use.

Prognoses of labor resources are closely connected with scientific-technical and demographic prognoses. These include prognoses of the occupation and liberation of manpower over the branches of industry as a result of automation and cybernetization, the redistribution of labor resources by branches and territorial regions, the preparation of specialists and retraining of personnel, etc. All of these, in the final analysis, will make up the prognosis of the effectiveness of using manpower in the country's national economy in the future.

The prognoses of natural riches are aimed at revealing the supplies and tempos of expenditures of a given type of resources, evaluating the financial and material expenditures on their mastery, etc. They include prognoses of the power, fuel, mining, nonmetallic, vegetable resources, and animal resources.

The prognoses of material resources include determining the perspectives of developing the tempos and structure of the socialist reproduction under various conditions (investment volumes, amortization time, diversification of investments, etc.).

In the prognosis of social requirements the tendencies of the demand for equipment, materials, raw materials, and power on the part of individual productions and entire branches are determined. The prognoses of the demand for consumer goods and various types of services are related to this.

Prognoses of social conditions as the background of the national-economy's development on the one hand and the social consequences of scientific-technical and economic progress on the other hand are an indispensible part of economic prognoses.

The described directions of the economic predictions are inseparably interconnected. Therefore economic prognoses are essentially complex and require the use of complex methods for their development.

Scientific-technical prediction is a business of capital importance, because it, in the final analysis, permits the most rational and effective socio-economic development of society, the maximum use of the advantages of the socialist economic system, further entrenchment of the positions of socialism in the struggle of the two worldwide systems in all areas - economic, ideological, scientific-technical, and military-strategic. The scientifically based prognoses will aid in uncovering the stable tendencies of scientific-technical progress, the basic directions in the development of production, in the expansion and use of the national income, occupation and productivity of labor, the development of natural resources, etc., thereby accelerating the tempos of the development of the productivity forces of our society.

Microscale prediction is called upon to provide an effective organization of the work of each individual enterprise and the development of its activity with the consideration of varying internal and external factors. The lack of such prediction at this level leads in practice to the fact that the control system at individual enterprises is not merely nonoptimum but is substantially uncontrollable. The production and marketing of the Dnepr and Kama everyday electric pumps can be used as examples of such a situation. They were issued by three plants - the Perm plant, the Novokakhovskiy plant, and the Khar'kov plant. Back in 1965 there were so many electric pumps that the marketing organizations refused to take new productions - the production from 1962-1964 lay in storage. Nevertheless, in 1967, 712 thousand electric pumps were planned to be issued (as compared to 90 thousand in 1965). And at the All-Union Trade Fair of 1967 a demand for 170 thousand devices annually was computed. The proposal exceeds the demand by 4 times. In toto the "production-marketing of electric" pumps: system turned out to be uncontrollable, and at two plants the manufacture of these pumps was ceased.

Prediction and planning are two inseparable stages of a single control process. Prediction is evoked to solve the following basic problems: to reveal the tendencies of the development of economics, science, and technology, to establish the true factors which determine these tendencies, to mark the perspective directions of investigations in the fundamental and applied sciences, to determine the laws and features of the foreseeable socio-economic and scientific-technical development, to examine variants in the development of the national economy in seeking the optimum solutions, and to mark the paths of the active effect on the economic processes for purposes of accelerating the tempos of the Communist system.

The scientifically based prognoses will become the foundation for developing plans of the socio-economic development of society,

the condition of optimum planning, and the control of the national economy. However, the deep differentiation of scientific disciplines inherent to modern science and the gigantic scales of investigations extremely complicate prediction and planning. Here are some main questions of prediction: the definition of the optimum relationship between the number of scientific workers in different branches of science, the perspectives of growth of scientific personnel in each branch, the financing of the applicable and fundamental studies, etc. In predicting scientific investigations it is necessary to consider the level and perspectives of science in other countries and in the entire world as a whole. And this is already a difficult problem in itself. To solve it we need the collection and processing of a tremendous amount of data.

Planning such a sphere of activity as a scientific sphere is also difficult by virtue of the fact that it is hardly possible to predict the results of the huge basic investigations before they are made.

However, the degree of indefiniteness, maximum at the stage of basic investigations, decreases at the stage of applied investigations and especially that of developments. Therefore, planning science is not only necessary but also possible - under the obligatory condition of the differential approach to the various categories and to stages of scientific-research and experimental-design operation.

It is important to establish proportions between the basic and applied investigations. Science cannot develop without free research, but society cannot limitlessly give such means to scientific works which do not give a rapid practical result. The problem of scientific prediction consists in particular of discovering any "optimum component" of basic researches.

At the applied stage, where losses increase by one order of magnitude, planning takes on a more habitual nature. But at the stage of developments, with an increase in losses even by one order of magnitude, the indefiniteness decreases to a minimum, and planning closely approaches the planning of material production. Beginning with this, the planning of science is ordinarily divided into perspective planning and current planning. The first has to do with future discoveries or the results of discoveries already made. The second, as a rule, has to do with the seeking of new areas and methods of applying scientific knowledge.

However, the original point of planning scientific activity should not be short-term but long-term goals. The long-term planning of scientific-technical progress in connection with such long-term demographic, raw-material, power, etc., prognoses is essentially the basis of perspective planning, while the latter is the basis of short-term planning of research and development.

In planning the development of science the applied investigations are centralized in essence and scale (volume). The basic investigations can be centralized but only in relationship to the planning of their volume based on accessible methods of scientific prediction and prognosing.

The centralized planning of science and technology should be accompanied by a long-term prediction of the directions of scientific-technical, economic and social progress. Such a prognosis in essence is a scientific hypothesis; it fulfills the role of a reference point for perspective planning. The purpose of prognoses is to indicate the perspective direction and tendencies and to note the approximate contours of the most important probable directions in science, the periods of solving huge complex problems, the volume of necessary material and labor losses, and the possibility of practically using the results of theoretical investigations. Naturally, predicting should be a continuous

process based on a well thought-out system of retrieving, accessing, and accumulating data.

What is the subject of prognosis in science?

The problems of scientific research (orientation periods of solving problems on the agenda, and defining the spectra of new problems, questions of the structure of science and the inter-realtionship among its different branches).

The social function of science - its place in society, science and technology, science and culture, i.e., science and other fields of social life.

The growth of the dimensions and volume of science (the problem requires development of a definite system of measures and appropriate policy).

To solve science-prediction problems it is absolutely insufficient to begin with a model whose basis is the idea that science is an autonomous self-regulating system whose motion is completely determined by inner impulses. We need to have a model in which we would get an adequate reflection of the place of science in society and its possible variation. In particular this assumes the development of criteria and a parameter of scientific and scientific-technical progress.

More help in solving this complex of problems can be rendered by a historic-scientific analysis which uncovers the prognostic possibilities of science. From this standpoint it is interesting to compile the "self-evaluations" of science with the characteristic of the stages it has passed through.

The primary problem is correctly planning the basic research, i.e., selecting the scientific subject and relationship between individual tempos.

For this we need a systematic compiling of periodical (for example every three years) data surveys about the state of each field of science, its new directions and tendencies of development. It should be noted that such type of systematic operation is beginning to be made ready in our country.

In our country there is a very ramified data service in the field of science and technology. At the first stage of the data operation abstracts in Russian on almost all printed matter available in the world are compiled and published. The second stage - the selection and analysis of data information - basically encompasses only applied research.

The organization of long-term planning of scientific activity has much in common with the organization of predicting scientific development. Expert evaluation plays a greater role in it. World-wide practice indicates the advisibility of dividing up the process of long-term planning into a number of stages of sequential detailing of design. The composition and sequence of the problems of developing scientific activity at each stage are determined through averaged evaluations of independent (external) expert groups. In the Soviet Union this function is executed by the scientific councils with the State Committee on Science and Technology and also by the Problem Scientific Councils of the Academy of Sciences. The Scientific-Technical Councils of Ministries of the Union Republics are connected at the stage of application here.

Relying on such a mechanism, the SCST has developed, for example, requirements imposed on the projects of the enterprises of the future in the coal, chemical and metallurgical industries. These projects provide an increase in the labor productivity 3-10 times based on new scientific and technical ideas.

The planning of scientific research is an inseparable component part of the total state planning of the development of

science and technology in the USSR. The plans of scientific research are confirmed by the government of the USSR, the councils of Ministries of the Union Republics and by the appropriate general state and republic organs as state acts which have the binding force for all scientific-research organizations.

Scientific-research operations are subdivided into four groups in terms of the meaning for national economy and methods of planning:

works which through the division have made up the State plan of scientific-research works and the introduction of achievements of science and technology into the national economy of the USSR;

works which are part of the plan of developing the national economy of the union republics,

departmental scientific-research subjects which make up the plan of the operations of the ministries, the State plan and other departments;

the initiative subject of scientific institutions not conformed by higher organizations.

At present the main form of planning sciences in the USSR is the State five-year plans.

The main scientific problems which need to be solved and the expected final results are established in the five-year plan. The purpose of the perspective plans is to stimulate the trends of scientific search and research operations on the problem recognized as most urgent and perspective. The most important problem of perspective plans is to create the process stock of scientific works, the liquidation of superfluous parallelism, and providing the correct specialization of scientific institutions.

Relying on the outline of perspective planning, the current planning in the field of science has the possibility of being more specific. It is realized as a rule directly at the level of scientific-research organizations. Current plans can include, in addition to the closest detailed remarks of a perspective plan, the tempos applied by the researchers themselves or the tempos advanced before them by the enterprises or other customers. The current plans, to a much greater extent than the perspective plans, are subject to economic evaluation which emerges here as the planning reference point.

There is great value in the correct determination of the continuation of the planned period for basic research on the one hand, and for applied research and development on the other hand. The experience of many countries shows that the most effective system of planning basic research is long-term plans for five years and more, corrected daily with the consideration of the actual course of the works. It is also important that in the plans not only individual tempos but whole complexes of scientific problems are provided along with the main research trends. The plans of applied research and development, as a rule, are compiled more correctly with the daily elaboration of the works to be noted and with the appropriate notations for years to come, which provides continuity in planning. Here, the tempos, stages of operation, their time periods, their appraisal over the entire subject and over each of their stages, and the expected effect are planned in already greater detail.

The presence of a large number of components in the development of many complex problems makes it necessary to compose co-ordination plans according to each problem. Recently methods of network planning of the control of scientific-research and experimental-design works are being ever widely introduced.

The progress of technology determines the level of the development of the entire national economy. The September Plenary Session of the Central Committee of the CPSU (1965) paid special attention to the necessity of developing plans with the consideration of the foreseeable trends in the development of science and technology. The national-economy plans are indicated in the statement of the Plenary Session of the Central Committee of the CPSU and should be considered as perspectives of the scientific-technical progress, and they should provide rapid tempos of introducing and mastering the newest achievements in science and technology, and they should be based on real and objective calculations.

The tempos of the development of our industry and agriculture also depend in the final analysis on the tempos of mastering the newest achievements in science and technology. Economists and planners have more than once expressed the necessity of developing scientifically based prognoses in the development of various branches of industry and the perspectives of mastering a new technique. An evaluation of the scientific prognoses should precede the development of plans in developing each branch of industry in order to give way to the leading and progressive in time, and to know in which direction to develop the plan.

No less important is determining the basic tendencies in the development of various branches of technology, the level of the development of worldwide and Soviet technology, etc.

Of the three basic types of prognoses - long-term, average-term and short-term - the most effective in the region of technology is the average-term time. The specifics in the development of technology and the rapadity of the expansion of knowledge substantially reduce the authenticity and the basis of prognosis over 20-30 years in advance. In turn, the short-term prediction (1-2 years) is closely connected with the temporary junctural factors. The average-time (3-10 years) prediction is more or less free from

the above shortcomings. Moreover, particularly this time is presently characteristic for developing the technical ideal of the appearance of the main idea of an invention until it is materially embodied.

It is important to emphasize that not only the level of technology as a whole, but also the specific scientific-technical solutions embedded in certain machines and mechanism, in certain of the technological progress to be developed, are subject to prediction.

In stating the problem of technical prediciton it is important to determine what specific elements of technology can be taken as objects of prediciton. As a rule such objects can include the following: the design or structure of machines, the technique of their production, methods of constructing the machine, and areas of applying the machines.

In the process of analyzing the object of prediction it is important to reveal the characteristics of each of the elements singled out as compared to elements of the same class which are optimum, in particular, according to the reasons shown below:

The design of machines:

the correspondence of the possibilities of the machine and the practical requirements on it,

the level of operational reliability,

longevity,

the production of work with minimum losses of materials, fuel, electrical energy per unit of production by means of production machines,

the technological progress of the design (labor losses and material losses);

the safety factor of the operation of servicing personnel.

The production technique:

the participation of man in the technological cycle (manual labor, mechanization, automation);

the coefficient of subdivision into technological-process operations;

the coefficient of connecting operations;

specialization of equipment and work areas,

time of technological cycle.

The innovation of design methods:

the main innovation of the method;

the innovation of the combination of known methods and means;

the known combination of unknown methods.

Expansion of the field of application:

the number of functional characteristics (universality of the machine);

the requirement of such functional characteristics in the various branches:

the uniqueness of the functional characteristics.

In predicting any branch of technology it is necessary to consider both the totality of the elements of technology singled-out above and each element individually.

The correctness of prognosis depends much on the prediction methods to be applied. In this connection the importance of creating methods of evaluating the prediction methods, analyzing the logic structure of prediction, the typology and classification of prognoses, etc., should be noted. The development of theoretical prediction problems is necessary. The basic positions of the theory of prediciton are presently in a state of creation and are already used in practice.

The effectiveness of predicting technology depends much on the organization of the data and patent business.

In research institutes the organization of departments for predicting the developmental trends in the branches of technology, new regions of its application, and the requirements of technology on the part of the national economy would contribute to a great extent to the widespread development of research works on the problem of prediction.

CHAPTER II

THEORETICAL QUESTIONS OF PREDICTION

THE FORMATION OF THE SCIENTIFIC DISCIPLINE OF PROGNOSTICS

Before we speak of prognostics as a scientific discipline, let us examine the question of the appearance of the problem of prediction.

Schematically the model of the prehistory of the problem of prediction can be represented in the following form.

First there appeared the practical problem of prediction and the appropriate theoretical question of the possibility of such a representation of the development of a specific object. This question was posed within the frameworks of the individual particular science and formulated in terms of this science.

If the question of prediction were not solved by the individual science, the requirement of using methods of other sciences to solve it would be investigated first, and secondly the main possibility of solving the given question would be used. In the first case the question of prediction outgrew the frameworks of one science and became an inter-scientific problem. In the second

case this analysis was made at the highest level of generalization, i.e., within the frameworks of philosophy.

At a definite stage of development in science the question of prediction arose on the agenda for all sciences without exception. Particularly in this sense it is necessary to understand the expression that one of the main functions of science is a forecasting function. And the heuristic value of scientific hypotheses or theory has begun to be considered in the plan of the possibility of predicting new facts based on this hypothesis or theory. The question of prediction was formulated as follows: by what method shall we build the structure of theoretical knowledge in order to compile a prognosis? Or in other words how are we to develop the method of predicting an object of a given specific science? If this question were solved within the frameworks of one science, its solution was often reduced to determining certain empirical relationships (for example, methods of prediction in hydrology).

However, the way of applying the prediction of a complex method, i.e., simultaneously applying methods of several sciences (mathematics, cybernetics, etc.) to solving the interscientific problem of prediction has proved to be more fruitful. Especially interesting in this plan are the works of the Soviet physiologist P. K. Anokhin on the appearance of the structure and laws of the functioning of a prediction device in the human brain and animals.

The problem of prediction is of such great significance for mankind that it has brought a new science to life - prognostics.

The admissibility of a similar genesis of the prediction problem is based on the fact that a similar path has been traversed and is being traversed by almost all complex problems. Cybernetics serves as a clear example. At first there appeared practical problems of creating automatic regulators for controlling various processes. Then there came the problem of data transmission and

controlling anti-aircraft fire. Then began the separate study of the principles of control and the connection with technical humanitarian and biological sciences. The synthesized approach to the problems of control and connection led to the formation of cybernetics as a complex problem. An in the final analysis cybernetics obtained recognition as an independent science. The synthesized approach to the problems of control and connection led to the formation of cybernetics as a complex problem. And in the final analysis cybernetics obtained recognition as an independent science.

For a more precise understanding of the prehistory of prognostics it is necessary to consider the following circumstances.

– The affirmation of materialism as the basic philosophical trend of modern times. The position of idealism in relationship to the recogiition of the future consisted and consists in negating the possibility and necessity of prediction. The future is an area of faith and not investigation - this is the viewpoint of idealists.

– Before Karl Marx materialism basically correctly explained the phenomena and processes occurring in nature. When we became concerned with human history, materialism gave way to idealism. Therefore, before Marx the place of scientific prognosis in the development of society was occupied by utopia.

– Dialectical materialism, as opposed to methaphysics, permits making extrapolations which in essence involve the development process.

– The Leninist theory of reflection and the modern concept of the leading reflection of reality is the general-theoretical basis of prognostics.

— In addition to the determined systems the discovery of stochastic processes and laws controlling them has expanded the possibilities of predicting complex systems.

— By virture of the intense development of science, the practical value of the prediction function of scientific theories has begun to be realized. Now prognosis makes up the content of each theory without fail.

"A characteristic feature of this stage in the development of science," notes Professor B. G. Kuznetsov, "is the inclusion of prognoses in the very contents of scientific theories. Therefore the question of the possibility of prognoses is now stated again. It would be truer to say that a similar question has given way to another: is the development of science without prognoses possible? The answer is negative: each however-broad attempt to advance the theory of elementary particles to any extent includes a direct or hidden reference to the perspectives of science."

— The development of questions of the theory of systems contributes to the development of analyzing the prediction object.

— The problems of control and connection formulated by cybernetics are interwoven with the problem of prediction since continuous prediction is a necessary condition in the control process.

— The principle of planning the development of the national economy and of the scientific and technical developments is inseparably connected with prediction. Scientifically based prediction should precede planning.

For the last 20 years the problem of prediction has been discussed by more than 40 international symposia and conferences of individual countries. Only at the beginning of the 50's did

the number of works on predicting the future number more than 1500 names. Among them are the prominent works of the physicist D. Thompson, the mathematicicians A. Kolmogorov, N. Wiener and L. Apostel, the physiographers P. Anokin and N. Bernstein, the economists A. Weinstein, S. Strumilin, F. Baade, et al.

The above facts once more confirm that the continuous process of expanding and deepening the complex problem of prediction led to the necessity of forming and developing the new scientific discipline - prognostics.

Prognostics as a scientific discipline is organically connected with practice. It answers questions of economic, social, scientific, technical, and other sides of the life of contemporary society. Here we will not examine the component parts of prognostics in detail, since it is a large and complex problem.

Prognostics is a scientific discipline which studies the general principles of constructing methods for predicting the development of the objects of any nature and law of the process of the development of prognoses.

The area of its application includes all systems of scientific knowledge without exception. In connection with the extreme divergence of the nature of the objects of various sciences and accordingly a specific description of their objects the entire field of application can be divided into subfields. But in this case the singled-out subfields will coincide with large groups of sciences in their classification system. In this sense it is right to speak of economic, scientific-technical, social, military, and many other prognostics, making it more precise each time that we are concerned only with the interpretation of the theoretical principles of prognostics on a system of knowledge which compiles the subject of the indicated sciences.

Science is a dialetical unity:

1. systems of concepts, categories, laws, etc.,

2. a method of recognition;

3. connection with the practice as the original point of a higher goal and a recognition criterion.

The presence of the enumerated three elements in the theoretical system of knowledge is a necessary condition for determining this system as a science. Let us examine whether prognostics satisfies this condition.

The history of many sciences testifies to the fact that the way of recognizing any object of the real world and the formation of the results of recognition in a scientific system which describes and explains this or that object flows in two directions. One way is the initial observation, classification, systematization and subordination, and then theoretically making sense of these facts, and discovering the laws and converting them into a method of obtaining new facts. Such an approach to recognizing an object can tentatively be called the inductive method.

With the second direction the theoretical system is constructed by advancing the original axioms, posulates, and rules of deduction by means of which we get a strict description of the laws of the behavior of the object. This method is characteristic for sciences which have reached a high level of development (for example, mathematics, symbolic logic, certain divisions of physics), and especially for metasciences.

The construction of prognostics in principle repeats the basic scheme of the recognition process from live contemplation to abstract thinking and from that to practice, i.e., from the concrete through the abstract to the concrete on a new level. At the

first stage (from the concrete) it is necessary to systematize and study methods for constructing and the structure of the prediction methods developed by particular sciences. The methods and processes of predicting the development of objects of specific sciences serve as that empirical material whose analysis and generalization will be the basis for formulating regularities. At the second stage (toward the abstract) the hypotheses and theories which explain the laws of constructing methods of prediction of the future characteristics of objects of various nature should be advanced. These hypotheses and theories will be checked (at the third stage) on objects of the field of interpretation.

The described method of constructing prognostics, however, does not exclude the deductive development of a theory of prognosis. Any limitations in this plan without making preliminary investigation is one of the conditions of the effectiveness of solving the problem and corresponds to the principles of dielectical logic.

However, the empirical-inductive and axiomatic-deductive ways of constructing prognostics are faced with one common problem without the solution of which none of them is possible: generating such a system of concepts which would permit adequately describing and explaining the facts and connections between them. Actually, the systematization and classification of the empirical material are unthinkable without specifically prognostic concepts; the success of constructing and formulating axioms or original principles of prognostics also depends on the presence of a system of concepts. Therefore creating such a system is a first-rate problem for the investigator. The general requirements imposed on the new concepts are formulated in the logic of scientific investigation.

The function of the original definitions, principles and axioms consists in the fact that to give an initial, let us even assume an abstract, understanding of the essence of the idea of a given science, they reflect the features of the subject to be

science, they reflect the features of the subject to be studied in its most general form. The original definitions, principles, axioms and general laws define the *method of the science* which is inseparably connected with its subject or is based on reflecting general regularities of the subject... The method includes the *decisive role and the construction of the system of the science,* since it uncovers its idea. Based on the position of the method the subordination of the concepts, categories and laws of the science are established.

The history of individual sciences indicates that a system of concepts of any science is not assigned a priori but is generated in the investigation process.

Prognostics is located at the stage of the formation of its specific method of investigation and system of concepts. But its connection with practice is already very close, since the requirement for prediction is extremely high.

As follows from defining prognostics, its subject is made up of all questions involving the development of methods for constructing the method of prediction and principles of compiling prognoses. Two prognostic main points are methods of prediction and the laws of the development of prognosis; they are interconnected and define the structure of the subject of prognostics.

But leading a conversation about these problems is impossible without solving the following problems:

a) classification of prognoses and defining the objects of forecasting;

b) the connection between the natural object of prognosis and the methods of its forecasting;

c) basic parameters of the prognosis;

d) the time for advancing prognoses, their accuracy, methods of evaluation and verification (check) of prognoses;

e) determining the stages of development of the prognosis;

f) classification and survey of existing methods of forecasting;

g) formulating methodological requirements to be imposed on predicting the social consequences of the scientific-technical revolution.

The solution to each of these problems depends on solving narrower problems which will be stated and examined in the appropriate chapters.

In the first approximation the structure of prognostics consists of three divisions: the method of forecasting, the process of developing a prognosis, and an evaluation of the prognosis.

The development of the indicated divisions relies on the data of the general theory of systems, cybernetics, various fields of mathematics, philosophy, logic, the theory of evaluations and on numerous facts obtained by specific sciences about the prediciton of their objects.

THE CONCEPTS OF "FORESEEING," "PREDICTING," "PROGNOSIS," "PLAN," AND "PROGRAM"

Man's activity has an explicitly expressed direction in the future. This found reflection in his language, in the appearance of such words as "foreseeing," "prediction," "prognosis," "plan," and "program." Generally designating the knowledge of man relative to the future of any process in the real world or future recognition

of any event (let us assume that it even took place in the past), the above five concepts are nevertheless different in content. Skipping an analysis of the numerous definitions in dictionaries, encyclopedias, monographs, dissertations and articles, let us give their working formulations. Let us only note the very unsatisfactory position with the definitions of the concepts in question.

By event we shall understand the appearance or change of an object and its parameters along with the phenomena and processes pertinent to the cognitive activity of the subject.

Scientific prediction is that part, direction, and stage of cognitive development of a subject whose result is obtaining knowledge of future events. Foreseeing is the evolution of live material developing in a process and the capability of a brain which anticipate reflecting reality.

Foreseeing:

is based on knowing the laws of the development of nature, society, and thinking and is the purpose of recognition;

is a form of the structural activity of the brain directed to reconstructing the picture of an empirically unobservable phenomenon;

is derivative or intuitive developing probable knowledge;

contains an informational model of future events;

can emerge as a method of scientific recognition.

The concept of "foreseeing" thus defined serves as a generic concept for concepts of "prediction" and "prognosis." Then by prediction we shall understand the foreseeing of such events whose

quantitative characteristic is either impossible (at a given level of the development of recognition) or is difficult.

In view of the necessity of identifying expressions as prognoses, the formulation of the concept of "prognosis" is introduced in a somewhat different plan from foreseeing and prediction.

Prognosis is an expression which fixes an unobservable event in terms of some kind of linguistic system and which satisfies the following conditions:

at the moment of expression it is impossible to unambiguously define its truth or falsity;

it contains an indication of a space or time interval enclosed and finite inside which the event to be prognosed occurs;

at the moment of expression it is necessary to arrange methods of checking the prognosis method, and a priori evaluation of the probability of the appearance of the event to be prognosed, and a check of the realization of the event to be prognosed.

Here are several words on the occasion of interpreting the terms in defining prognosis. It is assumed that the expression-prognosis is expressed in terms of an adequately developed linguistic system of the science which formulates the prognosis.

The language of this science is divided into three sub-languages:

1. The language of observation (proposals which fix the individual facts formulated in terms of observation).

2. The language of empirical constructs (proposals which fix the individual facts and empirical functions).

3. The language of theoretical constructs (proposals which fix the empirical functions and proposals expressing theoretical laws). If the basis of the prognosis is a theory formulated in the language of theoretical constructs, the rules for translation from the language of theoretical constructs to the language of empirical constructs should be shown.

In opposition to the well-known specialist on economic prediction Kh. Teyl', who considers prognoses not fixed by any of the possible methods as legitimate, our definition requires a graphic, magnetic, electric, or other type of recording or model fixation by any above method. [Translator's Note: No exact retransliteration of the name Kh. Teyl' from Russian presently available. Assumed to be non-Russian and non-Soviet.]

The term "unobservable event" means that the event to be prognosed at the moment of expression does not have to be given to us in the experiment. This standpoint is defended by a number of authors. Here it is appropriate to express the disagreement with Kh. Teyl', who indicates a fixation in prognoses of only unknown events. We can introduce a substantial number of prognoses of unobservable but known events. In addition, the term "unknown" suffers (if there is no special reservation) doubly: an event can be unknown to either society as a whole or to an individual person.

But let us return to our definition of prognosis as an expression which satisfies a number of conditions. The first one stems from the concept of prognosis as an expression of unobservable phenomena. Actually the concept of truth - the agreement of our ideas of truth - is applicable to expressions which fix the events given in an experiment, we can by no means state it in agreement with the event to be prognosed. If, however, such an agreement cannot be made, the expression is not a prognosis.

The second requirement is introduced to separate prognoses from numerous guesses, propositions, hypotheses, expectations, and simply fantasies. For an example, the expressions: "Man will surely fly to Mars," and "The result of the occurring scientific-technical revolution will be the complete liberation of man from hard physical labor" are not prognoses by definition. Moreover, a clear fixation of the place of the event to be prognosed on a time scale and the delimitation of prognoses and expressions relative to the main possibility of something are necessary. For example, the expression "In its lifetime the next generation will have Communism as its material-technical basis" is a prognosis, while "Mankind will enter into communication with extra-terrestrial civilizations" is not.

The requirement for checking the prediction method is dictated by practice. Actually, intuitive or voluntary prognoses can hardly be assumed based on the scientific compilation of plans, programs or control of any process. The basis for accepting a prognosis obtained by the given method for practical use can be served by references to:

any method if its correctness is checked on other objects and it permits obtaining the necessary prognosis;

the effectiveness and operational capability of a given method in the past in using it for objects of the same nature and degree of complexity;

logic strictness and consistency of the conclusion and agreement of the result with the basic laws of nature.

The term "means of verifying the prognosis method" is used particularly in the sense of executing these three points.

The necessity of first evaluating the probability of the existence of the event to be prognosed is caused by:

the impossibility of applying several prediction methods to the given object (concurring prediction methods);

the obligation of continuously evaluating the probability of the appearance of the event to be prognosed as it approaches the moment of its realization (this becomes clearer if we assume that prognoses are used in controlling any closed system where there is a feedback chain).

Checking the existence of the event to be poognosed aids in discovering the nonsense or triviality of certain expressions which seem to be prognoses at first glance. For example, "The growth of the population on the earth in the period of 1970-1972 will be positive and will be expressed by a finite number."

Let us now examine the relationship between prognosis and plan.

Time periods, volume, numerous characteristics, etc., in a prognosis bear a probability nature and must provide the possibility of introducing corrections. Such a possibility is available if the process of developing the prognosis is continuous. The specifics of prognosis still consists in the fact that their effectiveness is achieved only in the presence of several variants of the prognosis of the same event. A multivariable prognosis in a state can be considered as an entire spectrum of possible changes of the conditions, new circumstances, etc. Therefore as such changes appear we go from one variant to another, keeping, however, the possibility of optimum control of the process.

A plan, unlike a prognosis, contains unambiguously defined time periods and conditions of the realization of some event. Already by virtue of defining the concept of a plan as a previously noted system of means which provides order, sequence and periods for executing operations, the slight ambiguity of any indicator

must lead to the instability of the "building" of the plan. In connection with this, for minimizing the risk it is natural to leave any ambiguity to a part of the prognoses if we assume only one most rational variant of the prognosis for planned developments. Hence the relationship of the prognosis and the plan becomes clear. A prognosis is a preplanned development of multivariant models of an event, the realization of whose plan has to be compiled. For example, the perspective planning of scientific investigations, in the opinion of economists, consists of four basic stages:

analysis of prognoses and selecting the most rational variant;

development of the general perspective for a definite period;

developed coordination programs for making investigations;

plans for realizing the investigation results in the national economy.

If the plan includes measures on executing any work in the form of a sequence of stages, time periods and volumes, the program provides for the further development and the detailing of these elements of the plan. In programs the specific activators of operations, monitoring system, the account system, the system of coordination with other programs, etc., are ordinarily indicated. The program, as well as a plan, is characterized by unambiguity of indicators. However, the program can interact directly with a prognosis if continuous prognosing is provided. In this case the transfer to a new variant of prognosis should be accompanied by the introduction of appropriate corrections into the program without changing the plan indicators. The program, so to speak, is more mobile and dynamic than the plan, although the greatest dyamicity is inherent to prognosis. In a further discussion we shall use concepts of foresight, prediction, prognosis, plan, and program in the above sense.

CHAPTER III

INTERSCIENTIFIC PREDICTION METHODS

Modern science arranges a huge arsenal of means of predicting scientific-technical progress. All methods used by the various sciences for predicting the development of their object can be divided into three large groups:

general scientific methods (or logic means),
interscientific methods,
particular scientific methods.

General scientific methods of prediction are based on the application of a definite sequence of thinking operations for the object of prediction. As a result of this there is created a system of conclusions relative to the connection of the object of prognosis with those conditions under which it exists. General scientific methods are made up of everything by which the logic of scientific investigation is now arranged:

observation and experiment;
analysis and synthesis;
assumption and hypothesis;
induction and deduction;
analogy;
classification and systematization;
genetic method, etc.

Each of these methods is described in adequate detail in literature on logic; therefore we shall not put the reader's attention on them.

Interscientific methods are of greatest interest to investigators in various fields of science and technology, since they are applicable for predicting a wide circle of phenomena - from scientific discoveries to various economic indicators.

METHODS BASED ON EXPERT EVALUATIONS

The *"brain-attacks" method* became widespread in the 50's as a means of systematically explaining creative possibilities. The purpose of the method was to discover new ideas based on the intuition of a scientist in the "brain-attack" process.

A direct "brain attack" can be brought on by both individual persons and by groups. It originates from the hypothesis that in a large number of ideas there are at least several valuable ones. The following basic rules for evoking brain attacks are known:

formulate a problem in its basic terms and with only one focal point;

do not announce a single erroneous idea and do not stop the attack;

support any idea, even if its realization is assumed to be in the far future;

keep encouraging the participants for creating free discussion relationships.

The impact-group method assumes that a "brain attack" is conducted for the agreement and unanamity on any question among a group of 6 persons.

The **"operational-creativity" method** assumes that only the director of a project knows precisely the nature of the problem and possible approaches to its solution. The purpose of the attack in this case is to seek the most probable solution.

The Delphi Method. A scientifically based picture of the future of our world can be created by several methods. The essence of one of them is in generalizing and statistically processing the opinions of specialists relative to the perspectives of his field and of adjacent fields. This method was developed in the USA to solve a number of important military problems and is used by the coworkers of the Rand Scientific-Research Corporation of the USA, T. Gordon and O. Helmer, in their "Research Possibilities of Long-term Prediction," whose results were published in 1964.

Detailed questionnaires are delivered to the leading specialists and experts in the appropriate fields of science and technology.

The questions in these questionnaires are broken down into 6 large groups:

1. Scientific discoveries.
2. Monitoring the population growth.
3. Automation of human activity.
4. Successes in the conquest of space.
5. Prevention of war.
6. Military technology.

The procedure of conducting the inquiries are as follows:

the questions in the questionnaires are posed so that their

answers have some kind of quantitative characteristic;

the questions of the experts are conducted in several rounds, during the course of which questions and answers are more refined;

when individual prognoses deviate from the opinion of the majority, the experts are asked to substantiate their standpoint.

From round to tound the answers are statistically processed to obtain the generalizing characteristics.

The purpose of the "Delphi Method" is to reveal the predominent opinion of specialists on any question in a situation which excludes their direct debate but permits them to weigh their opinions again and again with the consideration of the answers and arguments of their colleagues.

The inquiry was conducted as follows.

The first stage. The experts were supposed to name in graphic form the inventions and scientific discoveries which will be made in the next 50 years. They were supposed to begin with the fact that these discoveries are required now. As a result 49 discoveries were made.

The second stage. With 50% probability the experts were supposed to indicate the time of the realization of these discoveries (either in one of the time intervals of the half-century in question, or in a time segment greater than 50 years or never). These probable evaluations were then combined and represented in the form of quartiles and medians. In statistics a median is the average magnitude in a statistic series. The quartile ranking of prognoses (i.e., the refinement of opinions - as a result of iteration) in the first approximation means the expected interval expressed by the median. If the median is year X (from the moment of the production of the prognosis to the date to be prognosed),

the lower quartile is put at a distance of 2/3 X, while the upper quartile is put at 5/8 X. For example, if the median of any event is 1975, and two quartiles are equal to 1972 and 1988, this means that a fourth of the experts assumed the date of this event (for which a 50-percent probability of its realization exists) to be before 1972, half before 1975, and a fourth only after 1988. Agreeing answers were obtained for 10 of these 49 named discoveries.

The third stage. Experts who set "opposing" answers about the above 10 discoveries were supposed to substantiate their opinion, which differed sharply from the majority. The discoveries on which no agreement was reached were presented again to the experts for examination to get additional argumentation of answers. As a result, narrower time intervals within whose limits the realization of these discoveries was expected were obtained.

The fourth stage. It was proposed for the experts to answer questions similar to the questions of the third stage for the purpose of narrowing down the time interval and the realization of the discovery even more.

The distinguishing feature of the Delphi method is the wide use of quantitative evaluations of prognoses. This method permits calculating:

the values of medians and quartiles;

the possibility of decreasing the quartile interval;

the correlation between evaluations of the data of realization of a discovery with the two probabilities of 0.5 and 0.9 (it is assumed that this correlation is a reflection of hidden "psychological connections" between these two evaluations).

Moreover, by means of the Delphi method we can also refine the list and nature of achievements in the region of science and technology in whose relationships the collection of prognoses was marked:

the time segment during whose course the specialist in question considers the appearance of the appropriate scientific-technical achievement with a 50% probability.

The authors of the report indicate several methodological defects of the conducted investigation (the instability of the composition of the groups in question, too great intervals - approximately two months - between alternate rounds of inquiry, an inadequately clear formulation of questions, and a very diverse and not always high qualification of the experts).

From our standpoint a very substantial defect of the inquiry was the complete disregard of questions of social development and social relationships.

As an example let us introduce the contents of the questionnairs for the experts.

Indicate the year when it will become possible:

to economically profitably distill sea water,

to create new synthetic materials for superlight structures,

to use machines en masse to translate from one language to another,

to transplant the organs of the human body and to create their prosthesis,

to make artificial organs made out of plastic and electronic devices come alive in the human body,

to reliably predict the weather,

to partially control the fallout of precipitates,

to create a single data center,

to discover and expand non-narcotic substances which change the psychics,

to create a single physical theory of phonema and processes,

to establish a functional universal communication system based on satellites, a general-purpose relay apparatus, and machines for automatically translating from one language to another,

to use distilled sea water for irrigating fields,

to create lasers in the X-ray and gamma-ray range of the electromagnetic spectrum,

to control thermonuclear energy,

to artificially create primitive forms of life,

to commercially produce a synthetic food protein,

to economically profitably use the bottom of the Pacific Ocean (to develop raw-material deposits, etc.),

to use the ocean as a source of obtaining half the food products of the world,

to limitedly and economically effectively control the weather in certain regions,

to repeatedly expand the regions of curable psychic illnesses,

to generally immunize against bacterial and viral diseases,

to biochemically remove inherited defects.

In addition show:

new sources for obtaining food,

new sources of energy,

new sources of raw materials and materials.

THE METHOD OF INTERPRETATION AND EXTRAPOLATION

In mathematics interpolation has an absolutely clear definition.

If a certain function $f(x)$ is given and its values $y_f = f(x_j)$ are known, where $j = 0.1, \ldots, n$, at points $x < x_1 < \ldots < x_n$, the determination of the values of this function at points x lying between points x_j is called interpolation.

The main conditions imposed on the functions in interpolation are as follows:

the function should be continuous and analytical;

for a specific type of function or its derivatives such inequalities are shown which determine the applicability of interpolation to the given function;

the function should have an adequate number of not too rapidly increasing derivatives.

The Lagrange-Newton, Stirling and Bessel interpolation formulas are most widely used.

A procedure resembling interpolation in form is used for predicting the parameters of the objects of any science. For example, D. I. Mendeleyev's prediction of new chemcial elements can be formulated as a determination of the values of the object of prediction at certain points inside the segment $x_0 \ldots x_n$ in accordance with known values of the parameters at points $x_0 < x < x_n$. Unlike mathematics, in other sciences there is no strict and clear formulation of the conditions of the legitimacy of interpolation. Thus, statistics speak of interpolation as the finding of indicators absent in a dynamic series of phenomena based on a revealed interdependence of the terms of the series, and the necessity of thoroughly analyzing the essence of the influence under study is promoted as the conditions. However, this condition is expressed by so many general phrases that it is practically incapable of operation.

Extrapolation in mathematics is understood as follows. If the value of a function is known at points $x_0 < x_1 < \ldots < x_n$, lying inside the interval $[x_0, x_n]$ is known, the procedure of establishing the values of the function f(x) at points x lying outside the interval $[x_0, x_n]$ is also an extrapolation. Extrapolation always gives approximate values of the function f(x) which have a certain error; it is ordinarily calculated according to formulas for each type of extrapolation.

Interpolation formulas are used very often for extrapolation.

In sciences whose objects are not defined to such a degree that the concept of a function can be applied to them, the term extrapolation is used to designate the logic procedure of the transfer of conclusions obtained inside the segment of observation (at a certain subset) to phenomena found outside the segment of observation (to a second subset or to the entire set).

The methods of predicting scientific-technical development based on the extrapolation of tendencies described below can serve as an example of the application of extrapolation for prediction.

This class of methods is based on the concept that any tendency fixed in the past and present will also act in the future, since changes of external and internal factors causing this tendency are not expected in the future. However, this concept is often untrue, since keeping the tendency primarily depends on its interaction with other tendencies, which cannot always be done. Nevertheless, the methods of extrapolating tendencies find wide application in scientific-technical prognosing.

Four groups of curves which reflect the different tendencies are calculated.

The first one is a linear increase of any parameter with damping at the end of the period in question. The mechanism of manual labor for the last 75 years can serve as the example of such type of tendency.

The second group is divided into two subgroups. pure exponential growth and exponents with saturation. Pure exponential growth is noted in the development of many parameters of functional systems - an increase in the maximum velocity of military and civil aircraft, the growth of the effectiveness of converting energy in

the technique of illumination (from parafin candles to gallium-arsenide lasers), etc. The graphical expression of these tendencies is pure exponents.

Exponents with saturation - logic or S-shaped curves - relate to the second subgroup. These curves can by symmetrical (the Lenz and Hartmann models) and asymmetrical (the Gompetz model). [Translator's Note: Exact transliteration of this name not found. Assumed to be either as transliterated, or could be "Hompetz." Not confirmed from available sources.] The Gompetz model describes many economic phenomena and is expressed by the following formula:

$$P = L \cdot e^{-be^{-kt}},$$

where P is the parameter in question, L is the parameter limit, b and k are constant magnitudes, and t is time.

The third group are curves which characterize a doubled exponential growth with subsequent saturation. The growth of the maximum velocity of particles in accelerators or the velocity of the calculations of computers used in banks, for example, relate to such tendencies.

The fourth group is curves with an initially slow and then a sharp exponential growth and subsequent saturation. The growth of the power of atomic and hydrogen bombs is a characteristic example of such tendency.

The reliability and accuracy of prognoses and tendencies of scientific-technical development can be increased if we apply this method in a complex with any other method (expert evaluations, etc.).

Quite frequently the free use of the extrapolation methods leads to paradoxes and oddities. Just such a case was described in artistic form by Mark Twain in his book, "Life on the Mississippi."

"In the space of one hundred and seventy-five years the Lower Mississippi has shortened itself two hundred and forty-two miles. This is an average of a trifle over one mile and a third per year. Therefore, any calm person, who is not blind or idiotic, can see that in the Old Oölitic Silurian Period, just a million years ago next November, the Lower Mississippi River was upwards of one million three hundred thousand miles long, and stuck out over the Gulf of Mexico like a fishing rod. And by the same token any person can see that seven hundred and forty-two years from now the Lower Mississippi will be only a mile and three quarters long, and Cairo and New Orleans will have joined their streets together, and be plodding comfortably along under a single mayor and a mutual board of aldermen. There is something fascinating about science. One gets such wholesale returns of conjecture out of such a trifling investment of fact."

In order to avoid falling into the position described by Mark Twain it is necessary to develop clear limitations and conditions of applying extrapolation as a method of prediction. Such a development can go by means of analyzing the numerous examples of applying extrapolation for prediction in the past and discovering general methodological principles of the admissibility of extrapolation in various situations.

THE SIMULATION METHOD

Simulation has become widespread as an investigation method in various sciences. The possibility of determining the correspondence between knowledge about subjects of knowledge and the subjects themselves is based on this method. Human knowledge about an object, materialized in the form of descriptions, images, schemes, etc., represents a more or less adequate reflection of the subject. But a materialized form of knowledge is also a model of the subject. The method of investigation in which not only the subjects of knowledge themselves are studied, while their models and results are made into a model of the subject, is called simulation.

Simulation is reduced to three procedures:

determining the model of the subject;

experimentation with the model (including a thought experiment);

by virtue of the symmetry of the relationship between the subject and its model, translating the conclusions obtained during the experiment to the object.

In the experimentation process (also including the thought experiment) with the model such connections, relationships or properties of the "system-model" elements can be established to which not one connection, relationship, or property of the "system-object" elements correspond. This can be interpreted in two ways: the constructed model is not adequate for the object, and the constructed model is adequate for the object; however the properties and relationships of the elements of the object are incompletely described. In the second case the third procedure of the simulation method is not something different from that which was predicted. There is a multitude of such predictions in science (the prediction of the positron, the neutrino, etc.).

Depending on the nature of the models several types of simulation are distinguished.

Subject - the reproduction of the basic physical, geometrical, functional and dynamic characteristics of the object on the model. Often the model is a subject constructed from the same material as the object.

Physical - investigation of the model of physical processes occurring in the object. In this case the theory of resemblance and the theory of dimensionalities are broadly applied.

Subject-mathematical - a description of the system of differential equations of the physical processes in the object with the subsequent solution to these equations on analog computers.

Signed (mathematical or logic) - this is a description of the object and the processes occurring in it with sets of letters (signs) of any alphabet with the operations of conversion on these sets and the interpretation of the results of the conversions in a definite subject area.

Informational - if one of the known machine languages is used during signed simulation as an alphabet and a general-purpose computer does the conversion.

All the described types of simulation can serve as methods of conversion. The problem consists in determining under which conditions the model takes on the prognostic function and what limitations and assumptions there are for interpreting any conclusion relative to the properties of the elements of the model and the relationships between them such as predicting properties and relationships between the elements of the object as yet undescribed.

Prediction by means of models became especially widespread in connection with the application of cybernetic technology. The following concepts are introduced with the analysis of the scientific-technical and socio-economic models.

The model - a description of certain aspects of the real world in simplified form; in the case of scientific-technical prognoses and in models attempts are made to consider as many nontechnical factors as possible which influence the progress.

Simulation - the functioning of the model during manipulations with its elements on a computer or manually.

Games (technical games for purposes of simulation) - a specialized form of constructing models of such a structure that they permit investigating the simultaneous interactions between the competing and cooperating players.

Of special interest is the evaluation of the cost and time expenditures on constructing models (the USA, for example):

at least two years are required to construct a full-scale model, although most models were created over 6 years (the largest model consists of 400 original equations);

the cost of constructing models varies from 25 thousand to 2.5 million dollars, and expenditures on socio-economic models can be within the limits of 50 thousand dollars; of 28 economic models 2 are played manually, 3 are "human-machine" games, 23 are machine simulation; of 29 socio-political models 10 are manual simulation, 5 are "human-machine" games, and 14 are machine simulation.

Games are an effective means of predicting the possible influence of a new or future technology. Games are divided into open and closed games on the one hand, and military and business games on the other hand.

Open games are mostly produced manually by virtue of the increased requirements on programming and the capacity of the computer memory. As a rule these are military games and games on the development of military technology for purposes of prediction. The ministries of defense of the USA and England systematically produce them.

Closed games to a great extent are determined systems in which certain human factors are subject to consideration and are partially formulated. In this connection closed games, as a rule, are simulated on computers. Business and military games can be closed games.

Business games were used first in the USA by IBM and General Electric at the beginning of the 50's of this century for

determining possible alternatives in the selection of a technico-economic policy. In particular they touched questions of increasing the assignments for this or that technical project, the simulation of the business of the firms in a specific struggle, optimization of benefits, etc.

As an example let us examine the "Game of the Future" of the American prognosticists Gordon and Helmer described by the known Austrian scientist E. Jansch. The leading American industrialists participated in this game. The players received a description of 60 possible tendencies between 1966 and 1986 (a doubling in the production of electric power, the prohibition of automobile traffic in the centers of cities, man's conquest of the moon, etc.), which were a synthesis of the technical, economic, political and social aspects. The participants in the game were divided into groups of two, three, or four persons each. Each player constructed his own "World of 1986" using a combination of 60 possible tendencies to force another player of his group to invest his own program. The winner was the one who received the most support for his "world."

Military games are ordinarily played either for predicting optimum stragegies in a future war or to predict more effective armament systems.

The model created by the command of the USAF can serve as an example of a military game. This is what an American journalist wrote on this occassion, "This model will help specialists of the USAF planning to select a weapon and maintain those systems which will lead to progress in the future. The results of its use will be a further study of the most promising systems and the creation of new programs for solving technical problems standing in the path of Air-Force development. The model permits checking many factors which should be considered in the process of accepting a solution such as objects of the national military policy,military functions, technical possibilities, cost and human resources.

Mathematical algorithms are compiled so that the system will be brought to reality, while the technique of optimalization to be used permits evaluating the resources of a tax year for the time of the game. Specialists on planning can convert various data directly in the machine in the simulation process. The model has a hierarchical structure of a government or industrial organization where we are required to evaluate the objects on the program of cost and expected results."

Models on the computer are used for both scientific-technical and economic predictions. An attempt to simulate a "knowledge-progress" macrotechnical-progress system is known. A simplified model was based on 37 variables and constants and 19 simple mathematical equations. It was calculated on tabulators. This model considered such factors as population, education, scientific-technical experience, the features of an investigation, etc.

The following four stages of a model scientific-technical prediction are proposed.

1. The representation of the future world in technical, economic, social, political and military fields with the consideration of national requirements. Tendencies are extrapolated and evaluations of their upper and lower levels are introduced. Scenarios are used in combination with optional simulation on a computer.

2. Relative probable evaluations are given.

3. Systematic error correction.

4. The integration of preceding stages by means of machine or man-machine simulation (this permits first to predict the tendencies, their interrelationships and structural changes in scientific-technical, economic, military, political, and social

models; secondly it permits investigating the consequence of the alternatives of the strategies to be planned).

THE PROBABILITY-THEORY AND MATHEMATICAL-STATISTICS METHODS

Statistic methods of prediction basically rely on the existing correlation connection between the objects of the real world. The concept of correlation is of its greatest heuristic value in the investigation of processes and phenomena which are not connected with cause-effect relationships. A correlation is ordinarily understood as the accompanying changes of one object during a change of another with which there is a correlative connection. Most often the correlations between two magnitudes is nothing more than the reflection of the action of the three magnitudes on them.

When it is desired to predict another event in the presence of a correlative connection between two events, regressive equations are ordinarily used. Simple regression is expressed by the equation y = bx + a, where a and b are coefficients which can be found upon solving the system of equations:

$$1)\ \Sigma y = b\Sigma x + na.$$
$$2)\ \Sigma xy = bx^2 + a\Sigma x.$$

If it is necessary to investigate a correlative connection between many events or magnitudes, multiple-regression equations are used during which the evaluation of the magnitude to be predicted is obtained from a linear combination of the independent magnitudes in question. A multiple-regression equation can be written as follows:

$$y = \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \alpha,$$

where β and α are constant magnitudes (they are determined by matching).

In evaluating the reliability of prognoses made based on a statistic correlation it is necessary to satisfy two requirements:

to check the obtained statistical material for consistency in accordance with a previously assigned coefficient of representation;

to substantiate the possibility of using the selected probability method for the phenomenon in question.

In literature it is often possible to en ounter expressions relative to the omnipotence of mathematical statistics. It is difficult to agree with those authors who proclaim methods of statistics as panacias of all prognostic woes. We are sooner inclined to join the opinion of J. M. Firestone who writes: "A number of suppositions should be the basis of any foresight or prognosis. If they are correct we will be able to make an accurate or sufficiently accurate prognosis. If the original positions are incorrect, the prognosis will be inaccurate regardless of how accurate the data based on it are... Statistics aid us in foreseeing, but in themselves they do not yet assure the possibility of correct foresight. By means of statistics we can get the best results in this relationship; however, in the final analysis everything depends on the original assumptions."

The prognostics problem is made up of the farthest investigation in expanding the possibilities of applying the ideas and theorems of the probability theories and mathematical statistics as prediciton methods.

ANALOGIES AS PREDICTION METHODS

Prediction by analogy has long been applied in various fields of public life. However, a systematic development of prediction methods based on analogy was begun comparatively recently. Let us examine these methods.

A method of predicting the development of technology based on analogy with the evolution of the animal world has been developed by the well-known scientist Lenz as a result of studying the works of the biologist R. Pearl, who from 1924-1925 established the interesting laws of the growth of the cells of white mice, the growth of fruit flies in a bottle, etc.

Making an analogy between the growth of biological parameters and the growth of scientific data, Lenz proposed a formula for the production of new data:

$$I = \frac{L}{1 - ae^{-bt}},$$

where I is the amount of data at moment of time t, L is the upper limit of data, t is time, a is a dimensionless constant, and b is a constant (dimension-time).

This formula is graphically expressed by an S-shaped curve. The formula satisfactorily explains such phenomena in science as the growth of the number of scientists, publications, etc.

Developing the analogy, Lenz proposes taking the following phenomena in science and technology as the object for prognosis:

Biological Growth	Scientific-Technical Phenomena
1. Analogy with cells	
original cell	initial idea or invention
cell division	invention process
second-generation cell	new idea or invention
period of cell division	incubation period of new idea or invention
nutrient medium	economic support of invention
cell lifetime	time of use of invetion
death of cell	moral depletion of invention

class of cell	class of machines
limit of cell-mass volume	limits of economic requirements imposed on inventions in a given field
size of cell mass	total number of existing inventions in a given field which have not become obsolete

2. Analogy with bisexual reproduction

male cell	existing inventions or discoveries
female cell	inventor
possibility of fertilization	communicability of knowledge
conception	appearance of an idea
embryo	growth of the new idea
embryonic growth	development of the idea
pregnancy	period required for invention
birth	appearance of invention
nutrient medium	economic support
maturation period	introduction into practice
maturity	wide use of invention
death	obsolescence
total number of male individuals	total number of inventions made minus the obsolete inventions

Lenz writes the following about the method of using this analogy for predicting scientific-technical development:

"We may predict the following by an analogy between cell division and the progress in science and technology:

"the time of doubling scientific-technical achievements (first establishing the average time period necessary for the appearance of a new idea based on preceding inventions);

"the ratio between an increase in finances and the number of inventions (this ratio is such taht the exponential growth of inventions is impossible without the exponential increase of economic support);

"the lower boundary of progress as a result of moral aging of inventions";

"the growth curve of the inventions to 'maturity.'"

The technical potential is a function of the number of inventors and financing. Then an increase in the economic potential can be directly related to economic support and the number of inventions. The prognosist can predict the volume of financing and the number of inventors, and based on this he can make a prognosis relative to the level of technical progress.

It is positively very tempting to make prognoses of scientific development based on the analogy developed by Lenz. However, the prognoses obtained here cannot be considered reliable if they are not confirmed by any other methods.

The method of prediction based on a qualitative historical analogy is often used in practical work on controlling various objects; however it found systematic application only comparatively recently in investigations made by the American Academy of Arts and Sciences. Their results were published in the book "Railroads and the Space Program - the Investigation of an Historic Analogy." It should immediately be noted that this book has no basis of admissibility for such a broad historic analogy. Important specific differences of modern society in the socio-economic and scientific-technical fields from the society of the past age are left out. Therefore, an analysis of the conclusions drawn by the American authors requires a critical approach. The problem of this investigation was to check the possibility of applying historical analogy for multilevel prognoses - from the level of technology and specific technical systems to social consequences. In this connection this transaction contains seven divisions of political,

technical, economic, social, and intellectual aspects of the expansion of railroads in the XIX Century. The science editor of this investigation B. Mazlish emphasizes two positions in this book:

the XX Century, being the "space age," can be evaluated by the same criteria as the XIX Century, which was the "railroad age";

the admissibility of historical analogies.

To further improve the historic-analogy method B. Mazlish proposes the following generalizations:

social devices touching all sides of the life of society (railroads, conquest of the ocean, space, etc.), are part of a social complex and give complex results (thus, they should be studied in a multivariant aspect, which was not adequately done in the above investigation);

social devices are developed in stages and have diverse effects at the different stages of their development;

all social devices carry the imprint of a national style which strongly influences both their appearance and development;

These points should have added to them the necessity of introducing qualitative indices which would permit more precisely comparing the prognoses of tendencies and evaluating their reliability. Practical significance of prediction by the historic-analogy method would then increase.

CHAPTER IV

METHODS OF PREDICTING THE DEVELOPMENT OF SCIENCE

PREDICITING THE LIMIT OF THE EXPONENTIAL GROWTH OF SCIENCE PARAMETERS

To define the basic parameters which characterize the growth of science there was developed a model based on the proposition that the increment of data per time unit depends on two factors - the number of scientists and a definite upper level of this number. This limit was called the saturation level. The connection factor between scientists was also related to the number of basic parameters.

However, the proposed model considered only the number of scientists

$$\frac{dI}{dt} = qN(t) = qN_0e^{ct},$$

where I is the amount of data (scientific knowledge), t is time, q is the productivity factor for one scientist per time unit, N_0 is the number of scientists actively working at a given moment of time, c is the dimensionless factor, and N is the number scientists in general.

This model corresponds with the investigations of D. Price who empirically established the law of doubling of the number of

scientist every 15 years. Integrating the precding expression, we get the formula of the exponential growth of scientific data

$$I = qN_0\int_0^T e^{ct}\,dt = \frac{qN_0}{c}\left(e^{cT} - 1\right),$$

where T is the time period which is of interest to investigators.

Subsequently this formula was corrected with the consideration of the growth limit of the number of scientists and the connection factor between them.

Thus, as a result of introducing the upper limit of the growth of information, the analytic expression for its increase will have the following form:

$$\frac{dI}{dt} = qN_0e^{ct}\,\frac{L-I}{L},$$

where L is the saturation limit. Integrating, we get

$$I = L\left(1 - e^{-\frac{qN_0}{cL}e^{ct}}\right).$$

The graphic expression of the formula is the so-called logistic or S-shaped curve.

A consideration of the scientific generalization (or connections between scientists) led to the following expression:

$$\frac{dI}{dt} = q\left[N + \frac{1}{2}N(N-1)\right] = \frac{1}{2}qN_0e^{ct}\left(N_0e^{ct} + 1\right).$$

He originated with the assumption that the maximum number of connections between scientists is expressed by the relationship

$$\frac{1}{2}N(N-1).$$

A real situation in science can be represented if we assume N >> 1, and then the increase of information will be described as:

$$\frac{dI}{dt} = \frac{1}{2}qN^2 = \frac{1}{2}qN_0^2e^{2ct},$$

After integration from $t = 0$ to $t = T$

$$I = \frac{qN_0^2}{4c}(e^{2cT} - 1).$$

In accordance with this formula the growth of scientific information occurs exponentially and with doubling.

A METHOD OF PREDICTING SCIENTIFIC-TECHNICAL DEVELOPMENT BASED ON A HISTORIC-LOGICAL ANALYSIS

The Soviet scientific consultant G. M. Dobrov in a number of works leads to a prediction of scientific-technical development from the positions of historic-logical analysis. The problem of prediction is considered as one of the problems of science and, consequently, a definition of prognosis; the problem of verification, accuracy, reliability of prognoses, etc., make sense only relative to the objects to be investigated by the science of sciences.

By the prognosis of scientific-technical development we understand the scientifically based data about the future of science and technology. "The content and degree of the reality of such prognosing data are determined by the historical experience accumulated by mankind, the knowledge and concepts inherent to the available level of science, and the possibilities whose realization depends on future generations." From this quote it follows that prognosis is the result of the treament of data accumulated and created by mankind in the process of historical development. This "raw material" of prediction, the original data, should be systematized and classified in a definite manner.

For this purpose G. M. Dobrov proposes using the idea of a thesaurus. "A generalized thesaurus is a certain formalized system (collection of information) which reflects with certain completeness our concepts of objects of information and the logic connections characteristic for these objects."

Three types of thesauri are examined: nominative Θ_f, and adequate Θ_a.

In the construction of the nominative thesaurus certain subjects of one class (an inventory report or specification of the parts of any technical device) are actually enumerated. The rules for formulating the nominative thesaurus do not provide for retaining the logic connections between objects when they are included into the thesaurus.

The adequate thesaurus is defined as a certain systematized collection inside which the connections and relationships between its objects are an identical reflection of regular connections of the subjects of a given class which exist objectively and are fixed by science. As a example we can indicate the sytematics of the elementary particles of Hall-Mann and Mendeleyev's periodical system of chemical elements. [Translator's Note: Mann, exact transliteration back into Latin characters not found. Assumed from context.] By virtue of fixation in the adequate thesaurus of the objectively existing regular connections it is the most logically capacious. The rules of its formulation provide the inclusion of objects and the fixation of regular connections between them. Based on the adequate thesaurus we can solve the problem of predicting new facts which, included in the thesaurus, can change its structure. It is assumed that such a change should take the direction of increasing the adequacy of the thesaurus.

The functional thesaurus is encountered most often in scientific-technical practice. "In constructing Θ_f we are no longer limited to the fixation of a known composition of objects of a given class, but we still cannot base the laws of the development of the objects discovered by science on its structure. Beginning with the empirical evidence accumulated in the course of engineering and scientific practice, in constructing Θ_f we attempt to reflect the base relationships between the objects to be systematized. Problems of defining the new combinations of

the thesaurus elements and predicting changes in the structure of of the thesaurus, etc., are solved based on the functional thesaurus."

Thus, the thesaurus can serve as a means of classifying and systematizing the data necessary for the prediction.

The prediction of scientific-technical progress is by nature a probability process. G. M. Dobrov proposed the following argumentation of this position.

Of an entire infinite set of facts (M) known and unknown by people, subset m is singled out; its elements are facts which make up a scientific system. This subset is represented in the form of a sphere with radius r. The surface of this sphere, proportional to r^2, is interpreted as the contact range of the known system of knowledge with unknown knowledge. Here the inadequate accuracy of interpretation should be noted, since the set of unknown knowledge is, following the terminology of G. M. Dobrov, also a sphere or radius $R >> r$, more precisely, $(R - r) \to \infty$. The Therefore it can hardly be said that the surface of a sphere with radius r is the contact range "with a residual mass of facts of the real world." Moreover, the absence of a clear definition of "facts of the real world, ... yet unknown to people" impairs the comprehension of the very fertile idea expressed by G. M. Dobrov.

In connection with the continuous growth of scientific knowledge, sphere radius (r) increases by (Δr), while the contact region of science with elements of set (M) accordingly increases in proportion to (Δr^2). Hypotheses about the development of science predicted for t years in the future are inevitably involved with an increase in the expected contact of science with the real world. Since there is a basis for considering an increase in the volume of science as proportional to time, the amount of new knowledge in science doubles every 40-50 years, while the amount

of scientific data increases doubly every 10-15 years. But a substantial portion of the facts important for the success of prediction are unknown, and we can only guess about them. Only the process of the interaction of future science with the real actuality gives a confirmation of the truth of the knowledge and causes certain of the scientific problems to be formulated. Hence the author draws a conclusion about the decrease of the probability of prognoses with an increase in the prediction time. Developing the interpretation further, G. M. Dobrov assumes that as a result of the constant internal rearrangement of the sphere of scientific knowledge (and the volume of this sphere is proportional to r^3) this circumstance should be considered in the evaluation of the relationship of knowledge with the lack of knowledge.

One of the most important characteristics of any prognosis is prediciton time. In the prediction concept under consideration the question of prognosis time periods is solved by the introduction of a concept of the time scales of scientific-technical prognoses. The first echelon composes prognoses with a prediction time of 15-20 years. This time period is substantiated by the following assumptions:

during this time 1-2 doublings of the number of scientific works put into practice should occur;

the total number of advanced technical ideas should also double;

the technical means of production should be completely renovated;

scientific ideas will traverse the path from fundamental investigations to the serial production of technical devices in which they are embodied;

the number of scientists should also double, while the number of scientific-technical workers increases 8-16 times.

The possibilities of science and technology determined already at the present time are the basis of the prognoses of the first

echelon; therefore their formulation is made up of both contents (qualitative) and quantitative characteristics of the object of the prognosis.

Prognoses with a prediction of from 40-50 years are related to the second echelon, since during this time:

the volume of scientific knowledge doubles (concepts, theories, etc.);

Θ_a is basically reconstructed;

the world population doubles;

the generation of the creators of scientific-technical progress changes.

Prognoses of this type are limited to fundamental laws and the principles of natural science; therefore the object of the prognosis is basically characterized qualitatively (by contents), although quantitative evaluations are also encountered.

Prognoses of the third echelon are a prediction time of more than 100 years. These bear a hypothetical character and are based mostly on intuition more than on a scientific system. Such prognoses are basically purely qualitative assumptions and contain no quantitative evaluations.

In evaluating the reality of scientific prediction G. M. Dobrov proposes considering three groups of limitations which determine the degree of accuracy of prognoses:

the laws of socio-economic expediency and the economic possibility of the scientific-technical decisions to be prognosed;

the laws and principles of natural science, a considerable part of which is seldom named according to the accurate expression of the leading physicist George Thompson, "principles of impossibility";

the most general laws of the development of nature and society ordinarily formulated in the form of the philosophical bases of the scientist's outlook.

All three groups of "limits," as a rule, are considered in prognoses relating to the first echelon. To a greater extent this also explains their relatively high accuracy. In prognoses of the second echelon the authors to a known extent ignore the conditions imposed by economic categories, while in the prognoses of the most remote third echelon they even more consider the historical relativity of the truth of a number of principles of science assumed now.

The prediction method under consideration is undoubtedly of interest.

A MODEL OF THE PARABOLIC GROWTH OF SCIENCE PARAMETERS

Numerous attempts to extrapolate the increase in parameters of any system when time changes of these parameters are subject to exponential law are known. For example, the development of science and technology during the last 100 years can be described (according to measurable characteristics) by exponential curves.

Thus, certain investigators compared the acceleration of scientific-technical progress with the activity of a new mass on a system of forces in equilibrium. The new mass introduces an accelerating component into the system's equilibrium. By analogy Lenz made the path traversed by the new mass conform to the amount of data accumulated by mankind, the speed of the system conform to the degree of data growth, and the acceleration of the system conform to the second derivative data in time. As a result he obtained a formula which describes the growth process of scientific-technical data.

$$\frac{d^2I}{dt^2} = g = \mathrm{const};$$

$$\frac{dI}{dt} = gt;$$

$$I = \int_0^T gt\,dt = \frac{g}{2}T^2,$$

where I is the data accumulated by mankind (scientific knowledge), t is time, T is the time for accumulating knowledge I, and g is the acceleration factor.

The analogy leads to a parabolic curve which sharply diverges into an equilibrium line.

It should be noted that the analogy has a substantial heuristic value; however, conclusions from the analogy are not proven and require further arguments. Moreover, the given model, as noted by E. Jansch, can no longer serve as a good approximation for describing two-parameter and multiparameter systems.

A METHOD OF PREDICTING THE GROWTH OF SCIENTIFIC-TECHNICAL PARAMETERS

The method of East Germany's G. Schrauber, a specialist in forecasting, is based on the general law of the growth of scientific-technical parameters. The law is formulated beginning "with theoretical reasons and by using and generalizing the results of a known or the predicted development of various fields of natural sciences and technology."

The essence of G. Schrauber's method is as follows.

The accumulation of objects of science and technology is characterised by effectiveness. If the effectiveness is determined by one parameter and is a function of means $M(t)$ expended entirely on the parameter, this can be expressed as

$$L = L[M(t)],$$

where L is the effectiveness. It has been empirically found that for effectiveness there exists an upper limit L_G which cannot be raised, i.e., $L < L_G$, and that the increment of effectiveness dL decreases with an increase, i.e., $dL \approx (L_G - L)dM$. Moreover, dL depends on the expended means

$$dL = (L_0 - L)f(M)dM,$$

where f(M) characterizes the effectiveness of the means used. Then the law of the growth of the parameter will be described by the differential equation

$$dy = (1 - y)\, n x^{n-1}\, dx$$

or

$$\frac{1}{1-y} \cdot \frac{dy}{dx} = n x^{n-1}.$$

From the above equation we can construct a number of growth curves for various values of n (the factor which characterizes the logistic curve).

G. Schaauber generalizes the obtained expressions for the case when the growth of parameter L_1 is connected with other parameters L_1, i.e., $L_1 = L_1(L_1)$, and in this particular case $L_1 = aL_1^b$.

This particular case, for example, is the connection between the digital-computer storage volume and access time t. The relative growth rates for the two parameters are proportional:

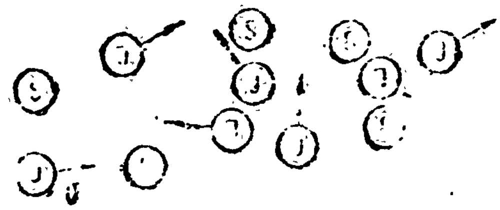
$$\frac{1}{L_1} \cdot \frac{dL_1}{dt} = b\, \frac{1}{L_1} \cdot \frac{dL_1}{dt}.$$

By means of the described method prognoses of the effectiveness and cost of long-term scientific-research works were made. These prognoses encompassed the period to 1990.

THE METHOD OF PREDICTING THE GROWTH OF SCIENTIFIC KNOWLEDGE

There exists a viewpoint in accordance with which the process of data exchange between two scientists can be represented as an interaction of the molecules of a gas in the process of any reaction. One type of molecule is the scientists, and the other is data quanta. The reaction takes place in a vessel with a

definite volume and density (the number of scientists per 1 m^3).



The "scientist-molecules" are at relative rest, while the "data-molecules" move at a constant velocity in different directions. It is assumed that the "production" of new data (or the useful reaction) occurs when the "scientist-molecules" have a definite reaction plane (the cross section of the vessel) Σ for collision with the "data-molecules." The data increment is described as an increment of the number of "data-molecules" per unit volume:

$$\frac{dI}{dt} = kvN\Sigma I(t),$$

where k is the proportionality factor; v is the speed of the "data-molecules"; N is the number of scientists; Σ is the plane of reaction; and I(t) is the amount of information.

After integration from t = 0 to t = T, assuming t = const, we get a formula of the exponential growth of scientific data

$$I = I_0(e^{bt} - 1),$$

where I_0 is the amount of data at moment t = 0, and b = kvNΣ = = const.

However, this formula should be refined in connection with the fact that the number of scientists is not constant but grows exponentially as was shown by many investigators. After correction, the data increment will be described by the expression

$$\frac{dI}{dt} = kvN_0\Sigma e^{ct} I(t)$$

and further

$$I = I_0\left(e^{\frac{kvN_0\Sigma}{c} e^{ct}} - 1\right).$$

A graphic interpretation of this formula on the logarithmic scale is a straight line.

From the positions of the saturation theory the model with the consideration of the saturation limit is corrected, and the final expression for data growth is obtained

$$\frac{dI}{dt} = (k\varepsilon\sqrt{\Sigma}) I \frac{L-I}{L} = bI\frac{L-I}{L}$$

and further

$$I = \frac{L}{1 + \left(\frac{L}{I_0} - 1\right)e^{-bt}}.$$

This model was criticized for the fact that it requires an ideal connection between all scientists and the entire data and the instantaneous use of each newly obtained data quantum. These conditions are not always met by far. But for small collectives the model can be useful in planning scientific investigations.

THE METHOD OF PREDICTION ACCORDING TO THE "TREE OF KNOWLEDGE"

To describe certain processes of the scientific-technical development we use a model based on the idea of the "tree of knowledge," whose branches are new scientific and technical achievements. The number of points of ramification is proportional to the number of branches of science and technology in which active ivestigations are conducted, while the amount of data to be obtained increases exponentially if each new field of investigations contains the amount of data necessary for discovery. The growth of data in each individual field is described by an S-shaped curve (complete development of the idea of any discovery) the same time as the total growth of data is subject to exponential law. This model is a good approximation in describing the processes of the growth of many functional systems.

CHAPTER V

METHODS OF PREDICTING THE DEVELOPMENT OF TECHNOLOGY

DETERMINING THE TENDENCIES AND PREDICTING SCIENTIFIC-TECHNICAL PROGRESS BASED ON A QUALITATIVE-QUANTITATIVE ANALYSIS OF THE DYNAMICS OF THE ISSUANCE OF PATENTS

The method of predicting the worldwide scientific-technical progress proposed by the Soviet patent expert and prognosticist B. M. Yardov, is based on the law of the accelerated development of science which was first formulated by F. Engels: "Science advances in proportion to the mass of knowledge inherited by it from the previous generation ..." Or in the symbolic expression

$$\frac{\Delta\Pi}{\Delta T} = \Sigma\Pi$$

where $\Sigma\Pi$ is the sum of mankind's preceding knowledge; $\Delta\Pi$ is the increase in knowledge over the period ΔT, and ΔT is the period for which the rate of the development of progress is determined.

In connection with the fact that for specifically analyzing the tendencies in scientific-technical development it is necessary to use the increment of knowledge, we introduce the definition of a unit of knowledge. As such a material unit, B. M. Yardov proposes taking the information about a new fact of science and technology which is concluded in a patent description. All further reasonings relate to an analysis of patent data. But the prediction method itself is based on the following assumptions:

the technical solution fixed in the patent will be put into serial production only over 10-16 years;

there exists a continuous connection between the dynamic data and scientific-technical progress;

certain deviations in data are counterbalanced by the laws of large numbers.

The first assumption - the generalization of the historic experience of patenting - can be considered as its own type of law in the development of technology. This has been repeatedly indicated by specialsists-patent experts: "At present the period between the creation of an invention and its application on the average consists of 14 years. It takes place from a year to fifteen years, while half the businesses of a given branch begin to use this invention."

The second assumption. Techno-economic processes are the support of the dynamics of patenting, which in turn is a reflection of the essence of these processes. It is a reliably established fact from which the specialists proceed in their investigations in the fields of economics, the science of sciences, history, technology, etc.

Finally, the third assumption is the specific appearance of the law of large numbers. Actually, the "umbellate," "doubling," "tactical," "misinforming," and "provocational" factors encountered in the general mass of patents can be considered as random deviations which are counterbalanced by the above law. This serves as a guarantee of the reliability of the conclusions to be obtained.

The prediction of scientific-technical progress by B. N. Yardov's method is nothing other than extrapolating the tendencies uncovered by analyzing the dynamics of patenting. The concept of the statistic experiment is the basis of the extrapolation processes of treating the series of the dynamics of patenting.

The statistic experiment permits:

discovering tendencies in the development of this or that specific technical device by a multiaspect analysis of the connections with other objects;

extrapolating these tendencies in the future for 10-20-25 years.

However, during extrapolation there is the probability of ignoring new tendencies. To reduce this to a minimum we recommend defining the first, second, third, and fourth derivatives of scientific-technical progress. B. N. Tardov proposes the following interpretation of derivatives: "The rate of the development of scientific-technical progress (first derivative - *Author's note*) reflects tendencies in the development of technological processes. An acceleration of progress (the second derivative - *Author's note*) reflects tendencies in scientific investigations. An acceleration of the acceleration (the third derivative -*Author's note*) indicates tendencies in the laws and principles of investigation (the transfer from some fundamental principles to others, the discovery of new laws - discoveries, pioneer inventions of qualitatively new tendencies). The fourth derivative probably reflects changes of the social conditions of scientific-technical progress in a direction to be determined by the mark of this derivative."

The analysis of the dynamics of patenting should be preceded by an evalu ion of inventions by the following criteria: the degree of the fundamental invention (pioneer or part), the degree of its quality of many aspects, how widely it is applied, its timeliness, and applicability in various branches of technology.

To specifically analyze patents from the above criteria it is necessary to construct a logic polyhierachical classifier of concepts. It is constructed in the form of a multi-trunk tree from one root (the subject): root-trunks-boughs-branches-leaves-veins and permits encompassing approximately 9000 simple concepts.

By analyzing the classifier we can determine the basic indicators of the development of scientific-technical progress: the growth tempo and the increment tempo. By growth tempo in the development of progress we inderstand the ratio of the number of patenting elements fixed in a given year to their average annual number for quite a large time interval. The tempo (acceleration) of the increment of progress is the ratio of the difference of the velocities in the development of progress to the number of years of the time interval in question.

B. N. Tardov also proposes formulas for the numerical definition of these indicators.

The tempo of worldwide scientific-technical progress

$$C = \frac{q}{m-n} \cdot \frac{\int_{n}^{m} \Pi(\Gamma)\, d\Gamma}{\int_{p}^{p+q} \Pi(\Gamma)\, d\Gamma} \cdot 100\%$$

Acceleration (increment tempo) of scientific-technical progress is

$$Y = \frac{dC}{d\Gamma} \cdot \frac{100}{\sqrt{C_m \cdot C_n}} \left(\frac{\%}{\text{год}} \right).$$

where C is the growth tempo or rate (relative) of scientific-technical progress (1st derivative from the function of an increasing number of patents - patenting elements), Y is the increment tempo or acceleration (relative) of progress (the second derivative), П(Г) is the change in the number of patenting elements (appearing per annum) in years, Г is the years of patenting, q is the number of years of the patenting period to be analyzed (ordinarily 15-20 years, the period of the patent's validity), p is the first year of the period, and m-n is the period for which the magnitudes (ordinarily equal to one year) are determined.

In accordance with the retrieval system developed by B. N. Tardov all classes of patents to which a given invention can be related (even if these classes are not put down on the patent) are subject to search. The consideration of the applicability of the patents in various branches of technology is thereby guaranteed.

In practice it is advisable to select the subject of investigation so that the number of simple concepts is within the limits of from 100 to 4-6 thousand. This corresponds to approximately 3-4 thousand patent descriptions which should be processed in the development of the classifier. The concepts are selected from the patent descriptions, and an index is conferred to each. The first digit of the index designates the class of the concept (trunk), the second designates the subclass (bough), the third designates the group (branch), the fourth designates the subgroup (leaf), and the fifth designates the sub-subgroup (vein). Further, opposite each index there are written the classifier columns which correspond to them (the terms reflecting the desired concepts). Definitions are given from the right side of the column, and further right the degree of term standardization is indicated; further the equivalents in English and French are shown. The contents of each of the patent descriptions is coded by 12 marks of the concept classifier. First of all the patenting elements are coded (up to 6). Afterward 6 more data are coded. This information is ordinarily contained in the description, the features, or patent formula. In the patent description there is information about the national patent classes and names of companies - owners of patents. This information is coded in the Bülow code (letters replacing numbers). [Translator's Note: Bülow appears to be non-Russian and is thus transliterated as if it were German.] The standard 80-column punchcard is ordinarily used in coding the patent description (for practically any patent 77 columns are enough).

Each patent is evaluated based on the developed concept classifier in accordance with the six criteria singled out above. If the index in the code lists by heading corresponds to the trunk or bough of the logic polyhierarchic classifier, the invention can be related to the cardinal or pioneer types; if the index corresponds to the leaf or vein the invention corresponds to an improvement of any part.

When several headings (indexes) apply to a patent description and a chain of concepts takes place, the degree of the capacity of many aspects of the invention should be indicated.

Using the above formulas we can predict the development of scientific-technical progress both by individual countries and by the world as a whole.

By means of the described method, tendencies in the development of scientific-technical progress in hydraulic-turbine construction, the designing of radio receivers, isothermic railroad cars, etc., were determined.

A SCIENTIFIC-TECHNICAL-PREDICTION METHOD BASED ON PATENT DATA

The method in question, proposed by the Soviet Patent Officer V. A. Obukhov, is one of the possible variants as shown by the author himself, of technically and economically analyzing inventions. Scientific-technical prediciton is understood as the autonomous link in the chain of preplanned developments:

determining and analyzing the development level of science and technology;

scientific-technical prediction;

economic prediction;

perspective plan.

The author proposes to divide the prognoses of the development of technology into five groups:

General-national prognoses - paths of the development of technology on the scale of the entire country.

Interbranch prognoses - an evaluation of the perspectives of solving complex technical problems.

Branch prognoses - directions of the technical development of individual branches.

Prognoses of types of production - perspectives of improving individual types of production or technological processes.

Detailed prognoses - a description and calculation of changes which can occur in individual units and parts of the machines.

The above groups of prognoses are compiled based on a technico-economic analysis of the inventions reflected in descriptions of patents and author's certificates. Based on the method there is proposed the idea of evaluating existing patents according to the n-degree system. Each patent is evaluated from two criteria: the value and perspectiveness of the invention. The engineering-technical significance factor of the invention (or the completeness factor) and index of profitableness R are introduced for their characteristic.

The completeness factor is the ratio of the sum of actual evaluations of an invention q to the sum of maximum possible evaluations Q

$$T = \frac{q}{Q}.$$

Theoretically the factor changes within the limits of from 0 to 1, but in practice $0.2 \leq T < 1$.

The significance and perspectiveness of the invention is determined from the table:

Factor	1.0-0.75	0.75-0.5	0.5-0.3	0.3-0.2
Perspectiveness of invention	very perspective	perspective	slightly perspective	not perspective

The specific values of q and Q are determined from a single table for each branch of technology in which the characteristics of the technical solutions appearing from the patent descriptions are registered.

An ordinal number or subscript (i_1, ..., i_n) corresponding to the place of a given characteristic in order of sequence is conferred to the characteristics in compiling the table. Each characteristic in turn is broken down into a number of positions p_1, ..., p_n in accordance with the individual attributes of the invention. As a result the table takes the following form:

Characteristic and positions	Evaluation (degree)
Characteristic i_1	
positions p_1......	 1
p_2......	 2
.	.
.	.
.	.
p_n......	.... n
Characteristic i_2	
positions p_1.........	1
p_2.........	2
.	
.	
.	
p_n.........	n

However, characteristics $i_1, \ldots, i_n$ ordinarily have a different value. For example, i_1 is an engineering-technical feature of an invention by which we understand one of the following points:

the improvement of parts of existing structures or individual stages of production (p_1);

the improvement of units of existing structures and a series of production stages (p_2);

the improvement of units of existing structures and stages of production at a new level of mechanization, automation, and network-control automation (p_3);

a new solution fixed by a basic patent (accompanied as follows by the reflecting patents (p_4));

a basically new solution, a discovery in a given field (p_5),

i_2 - the level of theoretical substantiation, i_3 - longevity of the structure, i_4 - the provision of the conditions of the safety technique in the production process, etc.

The point evaluations are multiplied by a correction factor to be determined empirically (see the table) for the equation of the significance of the characteristics:

	Characteristic i				
	1	2	3	4	5
Correction factor	0.992	0.984	0.960	0.884	0.626

Upon analyzing a patent basis in terms of any narrow subclass it is necessary to reveal the maximum possible number of characteristics. However, the author, based on experience, recommends limitations to a symmetrical five-link table in which the number of characteristics is equal to the number of positions and number of degrees, i.e.,

$$i = p = n$$

According to the opinion of the author, as a result of analyzing patents and determining the engineering-technical-significance factor the following are possible:

to obtain a quantitative expression of the engineering-technical significance of a single patent;

to explain the perspectiveness of using an invention in industry and the advisability of patenting it abroad;

reducing patents to their component form;

using a computer for the massive processing of patent stocks, since the formula $T = q/Q$ makes it possible to convert the qualitative features of a patent into quantitative magnitudes by means of the table.

The second criterion of evaluating an invention is its index of profit $R = \frac{D}{C}$.

Parameter D is ordinarily considered the cost of current manufactured articles, machine designs, and technological processes, including overhead and amortization deductions. Parameter C is the same cost as parameter D but for articles, machine designs, etc., which will be issued based on the new patented invention. Parameter R is determined from the following table:

Index of Profit	Characteristics of inventions's profitableness
$R \geq 3$	Highly profitable invention
$2 \leq R \leq 3$	Invention of average profit
$1 < R < 2$	Invention of low profit
$R < 1$	Unprofitable invention

The index of profit is determined by two methods: from the specimens of a ready production and based on its draft (at the planning-assignment level). As noted by the author, this method was tested in developing prognoses in the region of fundamental planning and gave positive results.

A METHOD OF PREDICTING THE DEVELOPMENT OF TECHNOLOGY BY EVALUATING THE ENGINEERING-TECHNICAL SIGNIFICANCE OF INVENTIONS

The method was developed by the Soviet patent expert V. G. Gmoshinskiy and tested in construction technology. As a premise we take the confirmation that the investigation of a retrospective patent fund for the past 5-10 years permits making a prognosis of the paths of the development of technology for the next 5-10 years.

The author singles out the following time periods: from 2 to 5 years - short-term, from 5 to 10 years - average, up to 30 year years - long-term, and above 33 years - very long-term.

It should be noted that the criterion of this division of prognosis time is not the only one for us. The principle of singling out these particular time periods together with many other similar divisions has one general disadvantage - subjectivity. The value of classifying prognoses by time periods is thereby reduced.

The prediction procedure is reduced to passing through three stages:

investigating and evaluating the novelty of a single patent;

singling-out concurring groups of patents of patent solutions and determining the perspectiveness of each of the three groups;

investigating and evaluating the patenting level in any field of technology.

As the author of the method himself notes, the main thing is the first stage. At this stage three of the most essential problems are solved: determining the cited number of patents, determining the cited flow of patent data, and determining the generalized completeness factor.

Let us examine these problems.

The completeness factor Γ in the method in question is the ratio of the sum of evaluations q of a given patent to the maximum possible sum Q, i.e.,

$$\Gamma = \frac{q}{Q} = \frac{\Sigma j_0 \psi(i)}{j_{max} \Sigma \psi(i)}$$

where j is an evaluation (stage) taken from the characteristic matrix, and i is the number in the ordered sequence;

$$\begin{matrix} j_{011}, & \ldots, & j_{01n} \\ j_{021}, & \ldots, & j_{02n} \\ \ldots & \ldots & \ldots \\ \ldots & \ldots & \ldots \\ \ldots & \ldots & \ldots \\ j_{0m1}, & \ldots, & j_{0mn} \end{matrix}$$

In this matrix each row is interpreted as a certain attribute or characteristic from which the patent is described.

In investigating specific patents the matrix has the form of a certain definite table (a thesaurus table according to V. G. Gmoshinskiy). Based on this table and the formula for Γ the algorithm of translating the qualitative features of the patent solution into the completeness factor is developed.

In evaluating the engineering-technical significance of the concurrent technical solution reflected in the patent there appears the problem of standardizing not only the positions of the characteristics but also the weight of the characteristics themselves (the degree of significance). This problem is solved by introducing the function $\phi(i)$, which standardizes the weight of the characteristics of the ordered sequence.

The final stage for the characteristics in the table is the result of multiplying the corresponding terms of the characteristic matrix by the standardizing function: $j = j_0 \cdot \phi(i)$. Standardizing function $\phi(i)$ is determined from the following relationships:
when $i = 1$

$$\varphi(1) = 1;$$

when $i \to 0$ $\qquad \varphi(i) = 0;$

when $i \to \infty$ $\qquad \lim \frac{\varphi(i+1)}{\varphi(i)} < p < 1,$

where $1 \leq i \leq \infty$ and $\qquad |\varphi(i)| > |\varphi(i+1)|.$

These relationships determine the value of the weights of the characteristics in the ordered sequence and the requirement of the convergence of the numerical series composed of the products of $j \cdot \phi(i)$. The attributes of d'Alambert, Cuchy, et al, can be used to prove the convergence of the series. As a result the standardizing function has the following form

$$\varphi(i) = \frac{i}{Q^{i-1}},$$

where $i \neq 0$, and Q is the numerical parameter whose value is determined empirically and is equal to 2. In other words

$$\varphi(i) = \frac{i}{2^{i-1}}.$$

The values of function $\phi(i)$ are represented in the table

The point occupied by the characteristic and ordered sequence.

	1	2	3	4	5	6	7	8	9	[illegible]
Value of function (the weight of the characteristic)	1	1	0,75	0,50	0,33	0,16	[illegible]	[illegible]	[illegible]	[illegible]

It has been empirically established that with practical accuracy (ε = 0.05 or 5%) the number of main characteristics for evaluating the patent amounts to 9-10. In the characteristic matrix the number of rows is equal to the number of columns, and in practice the necessary scale of values of the evaluation system is determined from the condition of the symmetry of the matrix. It was found that a five-point (j = 1, ..., 5) or ten-point

($j = 1, \ldots, 10$) system of evaluations is adequate for orientation calculations.

At the second stage there appear groups of concurring patent solutions, and the perspectives of each group are determined (for the average-term prognosis). The problem is solved by determining the introduced number of patents which is equal to the sum of the completeness factors for the related group of patent solutions:

$$M = \sum_{1}^{n} \Gamma.$$

The formula is legitimate, since the completeness factor leads the patent to an equivalent form. The evaluation is conducted according to the same characteristic table.

The investigation of the patenting level from any field of technology, conducted at the third stage, is reduced to determining the generalized completeness factor $\Gamma_{\text{об}}$. This factor is defined as the ratio of definite integrals for the reduced and rated flow of patent data:

$$\Gamma_{\text{об}} = \frac{\int_a^в M(t)\,dt}{\int_a^в N(t)\,dt},$$

where a and в are numerical limits. Here, by reduced flow of patent data we understand the functional expression of the gra, of the dependence of the investigated patenting on the preceding one (the graph is obtained by adding the numbers of the introduced patents). The rated flow is the same for nonintroduced patents.

As a result of investigating we obtained a table for evaluating the perspectiveness of an invention according to the completeness factor.

Completeness factor	Individual analysis of patents	Group analysis of patents	
	(advisability of putting the invention into production and patenting it abroad)	level of patenting (perspectiveness of patented solutions)	categories of patenting
1.0-0.8	very advisable	highest	I
0.79-0.6	advisable	average	II
0.59-0.4	slightly advisable	below average	III
0.39-0.2	inadvisable	low	IV

The total of the analysis of patents in a specific field of technology is this table and the determination of the degree of the advisability of patenting an invention abroad and putting into production based on this table. A similar method can be used to predict the development of narrow fields of technology.

SYSTEMATIZATION AND PREDICTION

In his works Yu. I. Rylev and his coauthors develop the idea of systematizing scientific and technical data based on such objective connections which determine every kind of aspects of analyzing the historical process. The analysis of historical development is based on the prediction procedure. Systematized data make it possible to most deeply and universally investigate the scientific-technical progress and, consequently, it is the most accurate and convenient factographic basis for prediction.

Systemizing is developed in two plans: a universal plan (the system of time-structure charts (SSTC)) and the aspect plan. A special significance is added to the development of systematization language in the form of various types of SSTC and conventional designation.

The authors first proposed classification and conventional designation by connections between events in the recognition process. Each connection is designated by the appropriate type of arrows with the code of the given event indicated on them.

The SSTC system serves as a means of fixing all knowledge accumulated by mankind and is constructed on three axes: time, structure (classification) and space (geographic). The main advantage of the SSTC system is the fact that it reflects the main objective connections of events.

The time (horizontal) axis is broken down by the decimal-calendar principle. Thus, for example:

a chart for 100 years is broken down into 10 segments of 10 years each,

a chart for 10 years is broken down into 10 segments of 1 year each,

and a chart for 1 year is broken down into 12 segments of 1 month each, etc.

The entire classification of the given subject is arranged on the structural (vertical) axis of the chart (or several charts).

Each chart relates to a definite territory (the world as a whole, a country, region, etc.).

The characteristic feature of the system is the principle of subordination (each subordinate chart is a scan of the part of the superior chart). The charts are scanned according to the divisions described above. Thus, the SSTC system can be represented in the form of a gradual pyramid whose base is the set of the most detailed charts with the reflection of the events of any degree of significance, while the superior stages of the pyramid are the charts of the more significant events.

The value of the proposed SSTC system for establishing the tendencies and persepectives in the development of science and technology, in the opinion of the authors, consists in the following:

the structure-time chart is a new document to be standardized, unique in form and structure (outside the dependence of the field in which the data in it consists) and serves as a basis for analyzing the scientific-technical progress;

the arrangement of data in historical and logical sequence provides a dialectical approach to studying the subject activity;

the coordination of the charts permits including an unlimited number of events into the system and to divide them in a multistage manner by significance;

the cross section along the vertical, reflecting the events of any degree of significance, gives the most complete, universal representation of a given moment (or period);

the cross section of the system along the horizontal permits seeing what has occurred for the time period to be observed of changes to any narrow (or wide) degree in any field of knowledge;

compiling the charts of individual geographic regions (or the country, for example) gives a most complete picture of the development of worldwide science and technology;

the staged charts make it possible to determine the moment of origin of an invention or discovery, the stages of its development from an idea to maturity into the technical medium or theory, the moment of disappearance, i.e., the entire lifetime of the subject under investigation and to reveal the tendency of the development as a whole.

In systematizing in all fields of science and technology there is created a unique picture of the scientific-technical process. The SSTC permits revealing the connections between as many remote fields as desired, finding the "blank spots" in investigations, etc.

Moreover, in the historic-structure chart system the authors see a basis for automating the process of storing and retrieving data by means of data machines.

Aspect systematization. Below there is given a short characteristic of the basic forms of aspect systematization: tables of tendencies, historical classification, tables of development, problem analysis, and balance tables.

Tables of tendencies. To overcome the difficulties in a general analysis of modern scientific-technical progress involving data redundancy we propose analyzing numerous factors and replacing the basic tendencies by analysis. The main tendencies should be revealed in branches and directions by specialists and be systematized by means of tables of tendencies. These tables form a general set of tendencies (on the order of several thousands) - a basis for a universal and interconnected analysis of the develomment of science, technology and economics in both retrospective and perspective plans.

Historic classification. Classification plays a substantial role in analyzing the development of subjects. It reveals various aspects and directions of an analysis. However, until now various subjects have been classified at various moments of time, and most classifications are not universal. Naturally, this makes a clear comparative analysis of the development of subjects impossible. Three types of historic classifications aid in overcoming the indicated disadvantages:

the 1st type - a complete historic classification - reflects the structure of an object (or knowledge of it) for the entire period of development;

the 2nd type - the classification of a period - reflects the development of the structure of a subject over a definite period;

the 3rd type - moment classification - reflects the structure of a subject for a definite moment.

Historic classifications can also serve as a basis for dividing the development of subjects into periods.

From the development tables we can clearly represent the change in the principles of action, the materials used, and other structural features of technical means at the stages of design, production, and use.

Each table is compiled for a separate subject. The problem aspect of analyzing consists in representing the entire history of the development of scientific knowledge as a continuous chain of problems becoming more complex when the solution to one problem involves the statement of new problems.

The absence of clarity in defining concepts "direction" and "problem" should be noted. The problem, unlike a direction, must have its own completion. Therefore it is necessary, in investigating the development of scientific thought, to intercoordinate directions, problems, and tempos.

DETERMINING THE LEVEL OF SCIENTIFIC-TECHNICAL DEVELOPMENTS AND THE TENDENCIES OF THEIR DEVELOPMENT

The method of patent officer I. Yu. Zborovskiy is based on studying the dynamics of the output of patents and an analysis of their qualitative characteristics. By dynamic patenting we understand the change of the number of patents and author's certificates issued for inventions over the time interval in question. By qualitative characteristics we understand the basic characteristic features which distinguish one invention from another (the height of the technical level of the invention, the width of the problem which is its basis, the complexity of the invention, the demand for it, etc.).

The prediction procedure in question is a five-link one, since it consists of five independent divisions - links.

The first link is investigating the dynamics of patenting any branch of technology. Methods of investigation in this direction are generally accepted; therefore the author does not concern himself with these methods.

The second link is determining the height of the technical level of an invention by which is understood the "importance of the technical solution which is its basis (invention - *Author's note*), i.e., is the invention a new direction in science or is it an improvement of solutions already known, or is it the application of a known solution for a new purpose"?

The author proposes to determine the height of the technical level of the invention by coefficient K_y, which "appropriately varies for each of the indicated groups in the following limits: 10-6; 6-4; 4-2.5; 2.5-1."

The third link of the procedure is investigating the width of the problem, which is the basis of the invention. As the problem's width criterion we propose to take a group of questions which it touches, "i.e., it relates to one important field, to a less important field or to special question." Any problem can be related to one of these groups. Each group is characterized by the value of the width factor $K_ш$. Numerous values of $K_ш$ vary within the same limits as K_y (from 1 to 10). The interpretation of the width of the problem is somewhat subjective. Thus, the last group (narrow problems) includes an invention for the method of determining an impurity in an individual chemical element. One can hardly agree with this, since the solution to the problem of obtaining clear and superclear materials, on the agenda for science and technology, depends to a great extent particularly on finding methods for accurately determining the amount of impurity in the element under investigation. To solve this problem methods of

chemistry, physics, cybernetics, and even biology are involved (the structure and functioning of the olfactory apparatus in animals).

The fourth link of the procedure is determining the complexity of the invention. "The complexity of the invention is determined by the complexity of the problem solved by the invention, i.e., a set of factors which should be considered in the solution to the problem and also the necessity in making calculations and experiments for solving the problem. In particular, the most complex group includes inventions created based on the consideration of factors not studied with the conducting of complex calculations and experiments to solve the problem; the next group includes inventions created on the basis of factors not deeply studied, simple calculations and experiments; the next group is based on known solutions with an experimental check and with calculations, and the last group - for creating inventions - does not require complex calculations." As follows from the segment quoted above, the following are necessary to evaluate the complexity of an invention:

1) clear criteria to determine the degree of studying the factors and their influence on the success of solving the problem;

2) unambiguous criteria to evaluate the complexity of the calculations;

3) criteria to determine the degree of reputation of the solutions.

The complexity characteristic is factor K_c.

The fifth link of the procedure is determining the factor of the demand for the invention. By demand for the invention the author understands the interest of inducsty and foreign companies in using the invention. This interest is determined as:

the critical requirement of industry in a given technical solution and demand for the sale of the license from a number of companies,

the absence of demands.

Demand factor $K_{спр}$ varies within the same limits of from 1 to 10. For various fields of technology the relationships between factors $K_у$, $K_ш$, $K_с$, and $K_{спр}$ are different. There is given a concept of a mutual significance (interconnection) of the factors, and its factor q, and there is introduced the unit for measuring the actual significance of the invention - the elementary invention in which all factors are equal to 1.

as a result of defining the above factors their values are substituted in the formula

$$K_{зн} = \sum_{1}^{n} K_i q_{ij}$$

where $K_{зн}$ characterizes the significance of the invention fixed by the patent.

The volume of scientific-technical developments of a given field in the time interval in question is determined from the following formula:

$$V_{нт} = \sum_{1}^{n} N_i K_{зi}$$

where N_i is the number of inventions with identical significance factors, $K_{зi}$ is the significance factor of one invention, and i is the number of inventions for which patents or author's certificates are given over the time interval in question.

Then the average level of scientific-technical developments is determined:

$$У_{ср\cdot н\text{-}т} = \frac{\sum_{1}^{i} N_i K_{зi}}{\text{[illegible]}}.$$

After determining the values of the average level $У_{ср\cdot н\text{-}т}$ over the years for a sufficiently long time period we can reveal the tendency of change in the average level and construct the appropriate graph.

In conclusion the subjectiveness of selecting the values of the proposed factors in the absence of clarity in the formulations should be noted. Without an additional substantiation of the series of the assumptions of the procedure it is difficult to recommend it for practical use.